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# Casualty Data Analysis of the World Merchant Fleet for Reported Fire and Explosion Incidents Resulting in Marine Pollution



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World wide merchant vessel fire and explosion casualty data were analyzed to determine the contribution of these casualties to the marine pollution problem. The source of information is the Lloyd's Casualty Information System Data Base. The Lloyd's data covers world wide casualty incidents for the period 1978 through 1992, regardless of insurance carrier.

The major findings of this analysis were presented for: 1) the overall fire/explosion problem for the world's merchant fleet, 2) lives and vessels lost as a result of fires/explosions, 3) all casualty categories contributing to marine pollution, and 4) fires/explosions contributing to marine pollution. General categories of merchant vessel types were identified and the circumstances surrounding the applicable casualty incidents were then categorized and analyzed for trends to the extent possible. Findings and general recommendations were provided to the United States Coast Guard.

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## PREFACE

The United States Department of Transportation (DOT), U.S. Coast Guard (USCG), has a longstanding commitment to safety of life at sea. The USCG Headquarters Office of Marine Safety, Security, and Environmental Protection (G-M) continuously looks for ways to improve and enhance marine safety onboard vessels with the focus on accident prevention and ultimately the preservation of life and the marine environment. The Oil Pollution Act of 1990 is an example of the United States' serious commitment to improve tanker vessel safety and preservation of the marine environment. Congress looked to the United States Coast Guard to develop, implement and enforce the OPA 90 regulations.

The Marine Technical and Hazardous Materials Division, International Fire Protection Section (G-MTH-4) is committed to preventing and minimizing the effects of fires and explosions to the worlds merchant fleet. This is accomplished by active participation and leadership in the International Maritime Organization from which regulatory modifications are made to the Safety of Life at Sea (SOLAS) Convention. In the interest of continuing to improve upon protection of human life, property, and the marine environment, G-MTH-4 recently sponsored this study. Analysis of available fire and explosion data was performed in order to quantify the magnitude of reported merchant vessel fires and explosions in the world merchant fleet that have contributed to the marine pollution problem.

The DOT, Research and Special Programs Administration, Volpe National Transportation Systems Center (Volpe Center) conducted this study. As a first step, cursory reviews were made of the Lloyd's Casualty Information System Data Base (Lloyd's), the National Transportation Safety Board Data Base, and the United States Coast Guard Casualty Data Base. Based on this review, it was determined that the Lloyd's data base provided the most comprehensive world wide perspective of merchant vessel casualty data for the purpose of this study.

Mr. Mark Gentile of the Volpe Center's Accident Prevention Division would like to thank Mr. Jack Westwood-Booth of the USCG, G-MTH-4 for his guidance and sponsorship of this study, and Mr. Pete Dickenson, Mr. Bruce Tessier, and Mr. Bob Marville of the Unisys Corporation for their Marine Engineering and Information Systems expertise.

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# METRIC/ENGLISH CONVERSION FACTORS

## ENGLISH TO METRIC

### LENGTH (APPROXIMATE)

1 inch (in) = 2.5 centimeters (cm)  
 1 foot (ft) = 30 centimeters (cm)  
 1 yard (yd) = 0.9 meter (m)  
 1 mile (mi) = 1.6 kilometers (km)

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### LENGTH (APPROXIMATE)

1 millimeter (mm) = 0.04 inch (in)  
 1 centimeter (cm) = 0.4 inch (in)  
 1 meter (m) = 3.3 feet (ft)  
 1 meter (m) = 1.1 yards (yd)  
 1 kilometer (k) = 0.6 mile (mi)

### AREA (APPROXIMATE)

1 square inch (sq in, in<sup>2</sup>) = 6.5 square centimeters (cm<sup>2</sup>)  
 1 square foot (sq ft, ft<sup>2</sup>) = 0.09 square meter (m<sup>2</sup>)  
 1 square yard (sq yd, yd<sup>2</sup>) = 0.8 square meter (m<sup>2</sup>)  
 1 square mile (sq mi, mi<sup>2</sup>) = 2.6 square kilometers (km<sup>2</sup>)  
 1 acre = 0.4 hectare (he) = 4,000 square meters (m<sup>2</sup>)

### AREA (APPROXIMATE)

1 square centimeter (cm<sup>2</sup>) = 0.16 square inch (sq in, in<sup>2</sup>)  
 1 square meter (m<sup>2</sup>) = 1.2 square yards (sq yd, yd<sup>2</sup>)  
 1 square kilometer (km<sup>2</sup>) = 0.4 square mile (sq mi, mi<sup>2</sup>)  
 10,000 square meters (m<sup>2</sup>) = 1 hectare (he) = 2.5 acres

### MASS - WEIGHT (APPROXIMATE)

1 ounce (oz) = 28 grams (gm)  
 1 pound (lb) = 0.45 kilogram (kg)  
 1 short ton = 2,000 pounds (lb) = 0.9 tonne (t)

### MASS - WEIGHT (APPROXIMATE)

1 gram (gm) = 0.036 ounce (oz)  
 1 kilogram (kg) = 2.2 pounds (lb)  
 1 tonne (t) = 1,000 kilograms (kg) = 1.1 short tons

### VOLUME (APPROXIMATE)

1 teaspoon (tsp) = 5 milliliters (ml)  
 1 tablespoon (tbsp) = 15 milliliters (ml)  
 1 fluid ounce (fl oz) = 30 milliliters (ml)  
 1 cup (c) = 0.24 liter (l)  
 1 pint (pt) = 0.47 liter (l)  
 1 quart (qt) = 0.96 liter (l)  
 1 gallon (gal) = 3.8 liters (l)  
 1 cubic foot (cu ft, ft<sup>3</sup>) = 0.03 cubic meter (m<sup>3</sup>)  
 1 cubic yard (cu yd, yd<sup>3</sup>) = 0.76 cubic meter (m<sup>3</sup>)

### VOLUME (APPROXIMATE)

1 milliliter (ml) = 0.03 fluid ounce (fl oz)  
 1 liter (l) = 2.1 pints (pt)  
 1 liter (l) = 1.06 quarts (qt)  
 1 liter (l) = 0.26 gallon (gal)  
 1 cubic meter (m<sup>3</sup>) = 36 cubic feet (cu ft, ft<sup>3</sup>)  
 1 cubic meter (m<sup>3</sup>) = 1.3 cubic yards (cu yd, yd<sup>3</sup>)

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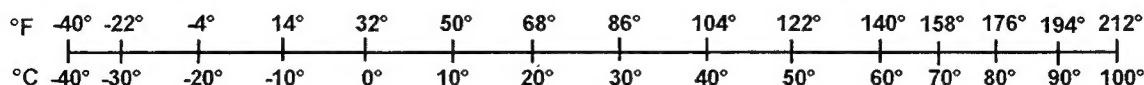
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## LIST OF ACRONYMS

BRG	Basic Retrieval Group (Casualty Categories)
DOT	U.S. Department of Transportation
DWT	Deadweight Tonnage
G-M	USCG, Office of Marine Safety, Security, and Environmental Protection
G-MTH-4	USCG, Ship Design Branch, International Fire Protection Section
GT	Gross Tonnage
IMO	International Maritime Organization
Lloyd's	Lloyd's Shipping Information Services, Lloyd's Register of Shipping, and Lloyd's of London Press, Ltd., Casualty Information System Data Base
LLP	Lloyd's of London Press Ltd.
LR	Lloyd's Register of Shipping
LSIS	Lloyd's Shipping Information Services
MARAD	Maritime Administration
NTSB	National Transportation Safety Board
USCG	United States Coast Guard
Volpe Center	Volpe National Transportation Systems Center

## EXECUTIVE SUMMARY

This "Casualty Data Analysis of the World Merchant Fleet for Reported Fire and Explosion Incidents Resulting in Marine Pollution" was performed to determine the extent of reported fire and explosion casualties that resulted in marine pollution. This was accomplished by analyzing vessel casualty data information contained in the Lloyd's Casualty Information System (Lloyd's) data base.

It was found that the Lloyd's data base supported the most comprehensive statistical overview of merchant vessel casualty incidents to the world's operating fleet for the reporting period of 1978 through 1992 (15-years). The contents of this report reflects an analysis based on this information.

The Lloyd's data base identifies casualty incidents under the following categories:

- Foundered
- Contact
- Fire/Explosion
- Collision
- Missing
- Wrecked
- War Loss
- Hull/Machinery
- Miscellaneous

The individual incident records generally contained only limited details regarding the causes of the casualty. The textual portion of these records typically include a very short description of the incident and its location on the vessel and then details of the damage sustained. An analysis to identify remedial actions needed to prevent the more common type of incidents would require more detailed information in the form of an investigative report.

The findings of this study are presented under the following major categories:

- 1) Fires/explosions
- 2) Lives lost and missing
- 3) Vessels lost
- 4) Marine pollution
- 5) Fires/explosions resulting in marine pollution

This analysis showed that fire/explosions were the 4th leading causal category of reported vessel casualty incidents. Hull/machinery, collision, and wrecked categories were the 1st, 2nd, and 3rd, respectively. Fire/explosions accounted for approximately 10% of all the reported casualties for vessels greater than or equal to 1,000 gross tons (GT).

On a fleet population basis:

- Passenger vessels were reported to have the highest fire/explosion casualty rate with an average of 2.7% of the fleet experiencing a fire/explosion in a given year.
- Tankers followed with an average rate of 0.9% of the fleet experiencing a fire/explosion casualty in a given year.
- Freighters and bulk carriers experience average fire/explosion rates of 0.5% and 0.4% in a given year, respectively. The freighter fleet has shown a significant decrease in the number of fire/explosion incidents experienced (from an average of 100 incidents per year decreasing to an average of 35 incidents per year).

Fire/explosion casualties are the 2nd highest cause of fatalities (2,177 lives), following the foundered category (2,805 lives). The majority of these fire/explosion fatalities occurred on tankers and passenger vessels.

Fire/explosion casualties resulted in the 3rd highest number of vessels lost (600 vessels). Foundered (660 vessels) and wrecked (658 vessels) categories resulted in the highest numbers of vessels lost.

The wrecked casualty category was reported as the most frequent cause of pollution incidents.

Based on the number of casualty records with reported pollution, the fire/explosion casualty category is not one of the leading causes of pollution incidents, ranking 7th out of the nine (9) categories.

The tanker fleet experienced the most casualties which resulted in reported marine pollution of all vessel types. The tanker polluting casualties represent an average of 35 incidents per year. Of these, fire/explosion casualties are a minor cause (8%), representing an average of 2.7 incidents per year (for an operating fleet of approximately 5,500 tankers). The leading categories of reported polluting incidents for tankers are hull/machinery, wrecked, and collision. For the most part, the volume of pollution for each incident was not available.

As expected, the tanker fleet is clearly the major contributor to the reported marine pollution problem by all casualty categories. For tankers the following was found with respect to the fire/explosion category:

- The most frequent site of the tanker fires/explosions was in the engine rooms.
- Boilers/main engines appeared to be the most frequent site of the "serious" fires/explosions.
- Repairs or hot work were taking place at the time of the majority of the reported engine room fatalities.
- Most of the tanker cargo area fire/explosion incidents, where the circumstances were reported on, occurred while hot work or other repairs were taking place.
- Approximately 50% of the cargo fire/explosion incidents were reported to involve fatalities.

As a result of this data analysis and based on the available level of information in the Lloyd's casualty records the following key recommendations are made:

- Based on our detailed review of information provided by Lloyd's and cursory reviews of the USCG CSMAN and the National Transportation Safety Board (NTSB) data bases, there appears to be insufficient world wide detailed causal data available. In order to derive sound statistically based remedial actions and assess the effects of current regulations on the world merchant fleet, this data needs to be accessible. Therefore, we recommend the USCG support and promote the development of a comprehensive IMO casualty data base with a focus on collecting detailed causal data, including system and crew responses to the casualty (or alternately, that the Lloyd's data base be enhanced). All IMO member countries should be strongly encouraged to actively participate in the submission of casualty data (anonymously, if need be).
- Based on the relatively high frequency of passenger vessel fire/explosion incidents and deaths with respect to the passenger fleet population, continue to promote fire safety design enhancements (i.e., automatic sprinkler initiative, smoke control, etc.), and fire safety training and awareness on passenger vessels. Develop an understanding of the factors effecting the significantly higher rate of fire/explosion incidents in the passenger vessel fleet in comparison to the other fleet types.

- A significant common factor in tanker fire/explosion casualties and related deaths was hot work/under repair going on at the time of the incidents. Evaluate the effectiveness of safety procedures and safety awareness related to performing hot work and repairs on tankers.
- Develop an understanding of the factors effecting the significant reduction of fire/explosion casualties to the freighter fleet.
- The wrecked casualty category resulted in the most frequent number of pollution incidents. Investigate circumstances surrounding these type of casualties to learn about causes and common factors.
- Perform a follow-on analysis of the National Transportation Safety Board casualty investigative reports that provide much greater detail surrounding the circumstances of the casualty events. This analysis should focus on the more frequent polluting type casualties identified within this study, (i.e., wrecked for all vessels, and hull/machinery and collision categories for tankers). In addition, develop an understanding of the circumstances surrounding the fires/explosions occurring in tanker engine rooms (location of 49% of reported tanker fire/explosions). The analysis should also include identifying the common elements of NTSB recommendations within their reports.

## 1.0 INTRODUCTION

### 1.1 PURPOSE AND OBJECTIVES

The United States Coast Guard (USCG) Headquarters, Office of Marine Safety, Security and Environmental Protection (G-M), International Fire Protection Section (G-MTH-4) has sponsored this study. G-MTH-4 will utilize the results of this study to provide both the USCG and the International Maritime Organization (IMO) with insight into the magnitude of, and reported causes of the oil pollution problem resulting from fires and explosions on merchant vessels. The conclusions and recommendations provided as a result of this study will help to aid in the decision making process by the USCG, where warranted, for potential future domestic and international regulatory fire safety initiatives.

The primary objective of this "Casualty Data Analysis of the World Merchant Fleet for Reported Fire and Explosion Incidents Resulting in Marine Pollution", was to determine the relative magnitude of the reported marine pollution problem resulting from fires and explosions onboard merchant vessels. General categories of merchant vessel types were identified and the circumstances surrounding the applicable casualty incidents were then categorized, and analyzed for trends to the extent possible. It is intended that the findings of this analysis will provide the USCG with insight into the magnitude of the fire/explosion problem as a whole, and with respect to marine pollution in particular.

In addition to meeting this primary objective, the study also provides additional insight into the fire/explosion problem with respect to the following:

- 1) Persons killed or missing,
- 2) Final disposition of the vessels as a result of the fire/explosion casualties,
- 3) Numbers of reported fire/explosion incidents by flags of registry, and
- 4) Numbers of reported fire/explosion incidents by Classification Society.

### 1.2 SUMMARY OF APPROACH

In order to present the magnitude of the merchant vessel fire/explosion/oil pollution casualty problem in the context of the world's operating fleet, the first effort was to identify the composition of the world's operating merchant fleet. This was done, for the years 1982 to 1992 using the mean population data for the overall world merchant fleet as reported by the U.S. Maritime Administration report "Merchant Fleets of the World." This data represents vessels greater than or equal to 1,000 gross tons (GT) and does not include vessels exclusively sailing on the Great Lakes, inland waterways, or military and specialty type vessels.

Next, an analysis was conducted to present world wide statistical summaries of the following: 1)an overview of Lloyd's casualty data for the period 1978 through 1992, 2)an analysis of the marine pollution problem and those incidents attributable to fires and explosions, and 3)reported fires/explosions as subsequent events for all casualty categories. At present, the Lloyd's data base provides the most comprehensive world wide data available for all merchant vessel casualties.

## 2.0 OVERVIEW OF WORLD WIDE CASUALTIES

The MARAD-published report on world fleet populations was limited to vessels of 1,000 Gross Tons (GT) and greater. Casualties to vessels of gross tonnage of 1,000 and upwards were therefore included in the analysis so that this data could be compared to vessel populations in the world fleet. Therefore, the Lloyd's casualty data for vessels between 100 GT and 999 GT was not included in this study.

The Lloyd's data base contains 233 vessel type descriptions. In order to maintain comparability with MARAD world fleet population data, it was necessary to categorize the Lloyd's vessel types into the following more general vessel types for comparison:

- Bulk Carrier
- Tanker
- Freighter
- Specialty Vessel
- Passenger Vessel
- Fishing Vessel

The approach to categorizing the Lloyd's multi-purpose vessel types was to consider the cargo and passenger carrying capabilities as the determining factors. Whenever possible, the casualty data was normalized by comparison to world population data for the type of vessel. When this was not possible, it was clearly stated (i.e., the reported numbers of casualty incidents with respect to the Classification Societies, as compared to the Classification Societies overall certification populations are not known).

The first phase of this analysis was intended to provide; 1) the overall world casualty perspective for all vessels, all casualties, 2) the overall fire and explosion casualty problem, and 3) the numbers of lives and vessels lost as a result of these casualties. Lloyd's categorizes casualties as "serious" and "non-serious". Casualties classified as "serious" essentially means that the vessel was disabled as a result of the casualty or experienced serious damage or financial loss. Since the classification of "non-serious" does not mean that there was no pollution or were no lives lost, it was important to consider both the "serious" and "non-serious" casualty categories in this analysis. Also, it was recognized that casualty rates needed to be compared against time, with consideration of changes in world fleet sizes, to determine if the casualty rates increased, decreased, or remained relatively consistent over the years reported.



## 2.1 WORLD MERCHANT FLEET

### 2.1.1 Merchant Fleets of the World Report Description

The "Merchant Fleets of the World" report presents a selection of ship statistics maintained by MARAD on the merchant fleets of all maritime nations. The first report in this annual series was produced by the United States Shipping Board for 1923. Formats have been revised over the years to extend its coverage and provide more useful information.

Statistics are presented for the fleets effective January 1, 1992, 1991 and 1982. Data is collected from public sources and U.S. Government records. Ships operating on the Great Lakes, inland waterways and special types such as channel ships, icebreakers, cablesips, and merchant ships owned by military forces are generally excluded. The report was prepared by the U.S. Department of Transportation, Maritime Administration, Office of Trade Analysis and Insurance.

### 2.1.2 Merchant Fleets of the World Report Definitions

The following applicable definitions are taken from the MARAD report:

1. Passenger/Combination Ships - Ships with a capacity for 13 or more passengers.
2. Bulk Carriers - Ships designed to carry dry bulk cargo. This category includes ore/bulk/oil carriers and other combination bulk/oil and ore/oil carriers.
3. Tankers - Crude petroleum, petroleum product, and chemical tankers, LNG and LPG tankers, wine, molasses, and whaling tankers.
4. Freighters - General cargo carriers, full containerships, partial containerships, roll-on/roll-off (RO-RO) ships, and barge carriers.
5. Gross Tonnage or Gross Registered Tonnage (GT) - The internal cubic capacity of the vessel expressed in tons (100 cubic feet to the ton) and measured in accordance with national tonnage regulations.
6. Deadweight Tonnage (DWT) - The carrying capacity of a vessel in long tons (2,240 pounds). It is the difference between the light ship weight and the displacement loaded.

### 2.1.3 World Merchant Fleet Overview

World fleet population data from the MARAD report has been used to normalize the Lloyd's casualty data. The following figure graphically presents the world merchant fleets composition:

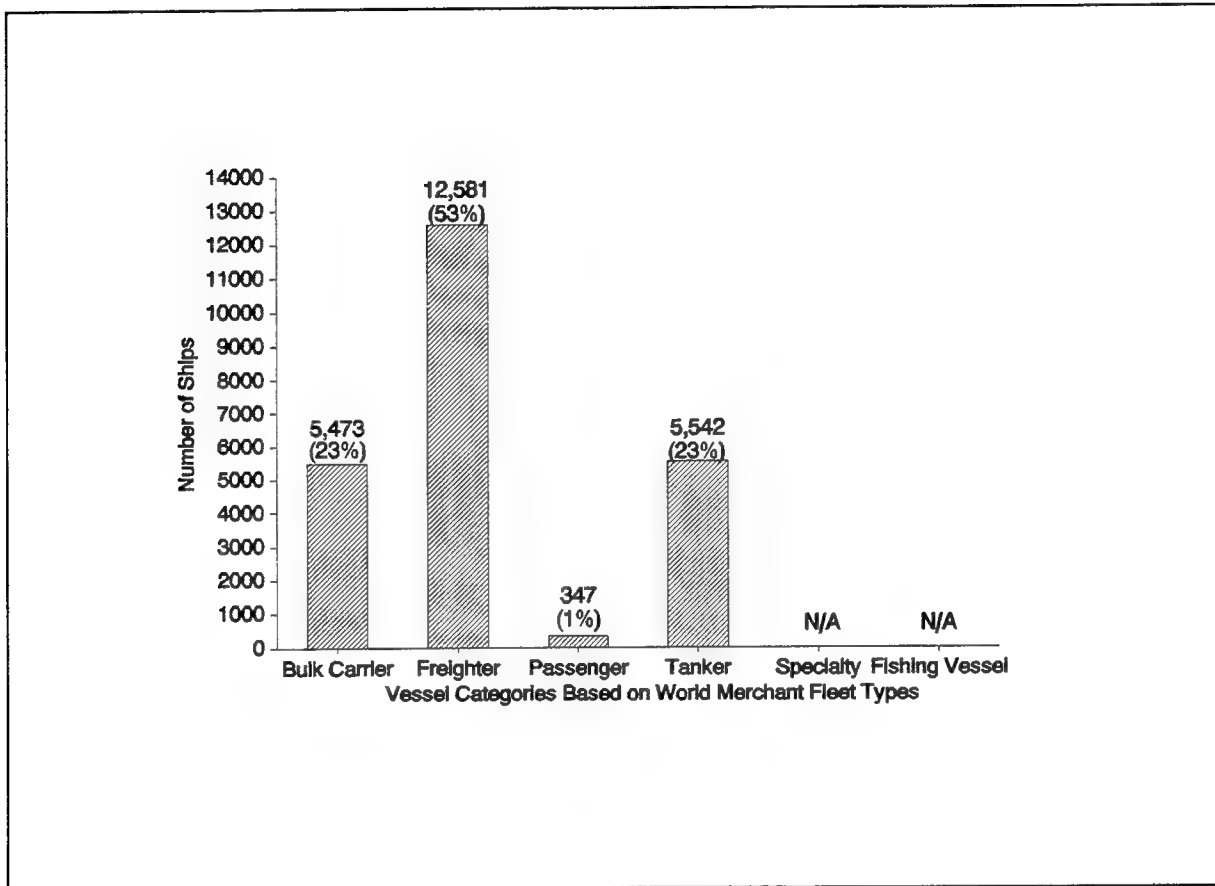


Figure 2-1

Composition of World Merchant Fleet  
(ships of 1,000 GT and over as of 1992)  
N/A = Not addressed in the MARAD report

The World Fleet ( $\geq 1,000$  GT, no lakers) totals 23,943 ships as of January 1, 1992. The MARAD "Merchant Fleets of the World" report covers the period 1982 to 1992. Overall, for the reported period of 1982 to 1992:

- Bulk Carriers have increased in number by 486 vessels;
- Freighters have decreased in number by 1,620 vessels;
- Passenger vessels have decreased in number by 58 vessels;
- Tankers have increased in number by 25 vessels, remaining relatively constant on a yearly basis.

## 2.2 WORLD MERCHANT FLEET CASUALTY OVERVIEW

### 2.2.1 Lloyd's Casualty Information System Data Base Description

Since 1734 Lloyd's List, now published by Lloyd's of London Press, Ltd. (LLP) has contained reports of casualties to ships.

Lloyd's Register of Shipping (LR) has published the Register of Ships since 1764, and quarterly and annual casualty returns of merchant ships totally lost and broken-up since 1890. Lloyd's Shipping Information Services (LSIS) represents a joining together of the information resources of Lloyd's of London Press, Ltd. and Lloyd's Register of Shipping.

In response to the shipping community's growing need for more detailed information on casualties and demolitions, LR has developed a casualty data base incorporating LLP's casualty reports, complemented by it's own follow-up and validation systems.

#### Volume and Range of Information

The Lloyd's data base contains accurate and comprehensive details of all reported serious casualties, including total losses, (as defined) to all propelled sea-going merchant ships in the world of 100 GT and above from 1 January 1978 and all reported incidents (serious and non-serious) to tankers, including combination carriers and gas carrier/tankers, since January 1, 1975. Also, included are records of ships broken-up or otherwise disposed of, not consequent upon casualty.

Reports, from which the file is primarily updated, are received daily from Lloyd's Agents and Lloyd's Register Surveyors, situated in over one-hundred and twenty countries. Validity checks built into the computer update programs ensure that coded data is input to the data base in an accurate form. The data base is updated daily and is maintained on an IBM 3033-N Mainframe Computer.<sup>(1)</sup>

The Lloyd's data base represents all reported merchant ship casualties world wide from the various above stated sources, regardless of insurance carrier. In addition, Lloyd's of London Press, Ltd. is utilized as an information source.

The Lloyd's data base contained reports of 34,687 casualty incidents, accumulated through the years 1975 - 1992, of which 2,370 casualty incidents (10% of the casualty incidents) are reported as fire/explosion casualties to ships of 1,000 GT and larger.

<sup>(1)</sup> Source - Lloyd's Shipping Information Services, Lloyd's Register of Shipping, and Lloyd's of London Press, Ltd. Casualty Information System Data Base Guide, 1983 revised.

## 2.2.2 Lloyd's Casualty Information System Data Base Definitions

The following applicable definitions taken from the Lloyd's Data Dictionary describe the casualties:

1. Marine Casualty - Is, for the purpose of the Casualty Information System, any incident occurring to a propelled, sea-going merchant ship of 100 GT and above in which the condition of the ship suffers adversely.

2. Serious Casualty/Serious Incident - Is a marine casualty to a ship, as defined, which results in:

- (a) Structural damage, rendering the ship unseaworthy, such as penetration of hull underwater, immobilization of main engines, extensive damage, etc.
- (b) Breakdown.
- (c) Actual total loss.
- (d) Any other undefined situation resulting in damage or financial loss which is considered to be serious.

3. Pollution - Concerns the loss of polluting substance(s), to the environment, from the subject ship in casualty. Only those pollution incidents occurring as a result of casualty (as defined in 1. are recorded on the data base. The absence of reported pollution does not imply no pollution occurred.

### 4. Casualty Categories - Basic Retrieval Group

Basic Retrieval Group (BRG) - Enquiries regarding casualty type may be answered rapidly and conveniently by selecting on these Basic Retrieval Groupings which are broad categories defined by LSIS. Enquiries concerned with the nature of individual events within a casualty may be answered through the more complex and detailed event coding system.

[Note - For the purpose of this report BRG is the same as the casualty category. Refer to Table 3-9 for validation of the BRG and subsequent reported events.]

4.1 Foundered - Includes ships which sank as a result of heavy weather, springing of leaks, breaking in two, etc., and not as a consequence of categories 4.2 - 4.7 or 4.9.

4.2 Wrecked/Stranded (includes grounding and bumping over bars, etc.) Includes ships reported hard and fast for an appreciable period of time and cases of reported touching sea bottom. This category includes entanglement on underwater wrecks.

4.3 Contact - Striking or being struck by an external substance but not another ship or the sea bottom. (see categories 4.2 and 4.4). This category includes striking drilling rigs/platforms, regardless of whether in fixed position or in tow.

4.4 Collision - Striking or being struck by another ship, regardless of whether underway, anchored or moored. This category does not include striking underwater wrecks.

4.5 Fire and Explosion - Where the fire and/or explosion is the first event reported (except where first event is a hull/machinery failure leading to fire/explosion).

[Note: It therefore follows that casualties involving fires and/or explosions after collisions, strandings, etc., are categorized under "Collision", "Stranding", etc. Scavenge fires and crankcase explosions are included in the "Fire/Explosion" category.]

4.5.1 Fire and Explosion Amplified Definition - Any ship towed into port is a serious casualty.

Shore assistance or assistance from another ship does not necessarily make the incident a serious casualty, this being dependent on the extent of damage. (i.e., shore assistance to a ship alongside a jetty).

For extent of damage to make an incident a serious casualty it would be necessary for structural damage to have occurred such as the deck to be ruptured or hatch covers blown off a combination carrier, damage to essential equipment, such as electrical wiring in the engine room, sufficient to delay the ship for at least four or five days, or damage to the accommodation involving the bridge or of sufficient extent that the ship cannot continue operating.

Damage putting a cargo or other non-essential pump or equipment out of action does not qualify as serious.

4.6 Missing - After a reasonable period of time, no news having been received of a ship or its fate being therefore undetermined, the ship is posted as "Missing" at the Corporation of Lloyd's and is included in the Missing Category on the data base together with similar cases reported by other reliable sources.

[Note: In peacetime, missing ships are considered as losses by marine perils.]

4.7 War Loss - Damage During Hostilities - This category is intended to encompass damage or other incidents occasioned to ships by hostile acts.

4.8 Hull/Machinery Damage - Includes ships lost or damaged as a result of hull/machinery damage or failure which is not attributable to categories 4.1 - 4.7 or category 4.9.

4.9 Miscellaneous - Includes ships which have been lost or damaged which, for want of sufficient information, or for other reasons, cannot be classified.

5. Vessel Disposition - Volpe Center consolidated Lloyd's dispositions into these two general categories:

Lost - Vessel has been scrapped, sank, or demolished as a result of the casualty.

Back in service - self explanatory.

### 2.2.3 Lloyd's Casualty Information System Data Base Overview

The casualty experience of the world fleet is summarized in Figure 2-2. The source of information about these casualty incidents is the Lloyd's data base. Figure 2-2 represents all Lloyd's casualty data by major casualty categories for all vessels of 100 GT and over. These casualty categories represent all "serious and non-serious" casualties as 1st events, except when a hull/machinery casualty led to a fire/explosion. In this latter case, Lloyd's categorizes this casualty as a fire/explosion.

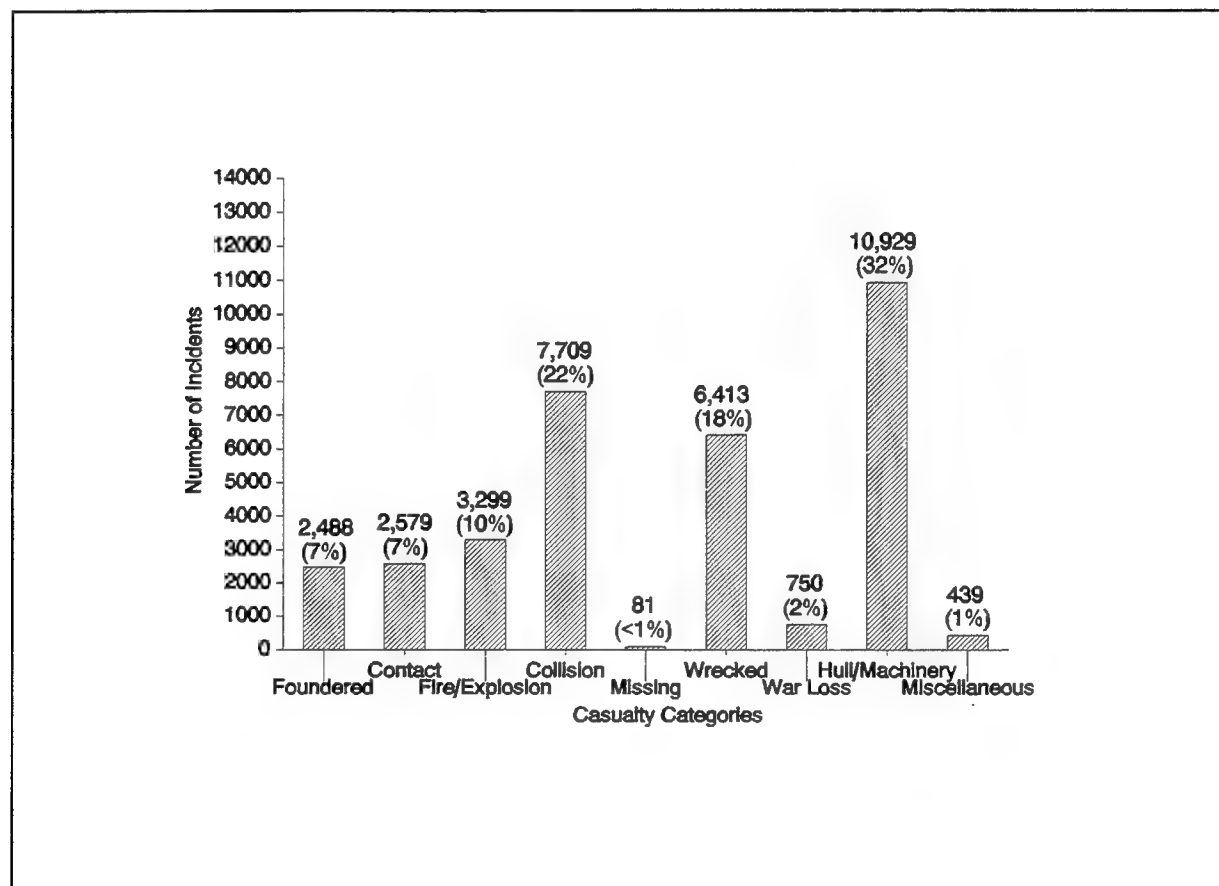


Figure 2-2

Number of Incidents by Casualty Category for All Vessels,  
1978-1992 (ships of 100 GT and over)

#### Summary:

Fires and explosions resulted in 3,299 incidents over the 15-year reporting period, or 10% of the overall general casualty problem. The fire/explosion category represents the 4th overall contributor of casualties to all vessels  $\geq$  100 GT.

Casualty data for vessels which would be included in the world fleet population data represented in Figure 2-1 (ocean-going vessels  $\geq 1,000$  GT) has also been summarized. This summary of results is shown in Figure 2-3.

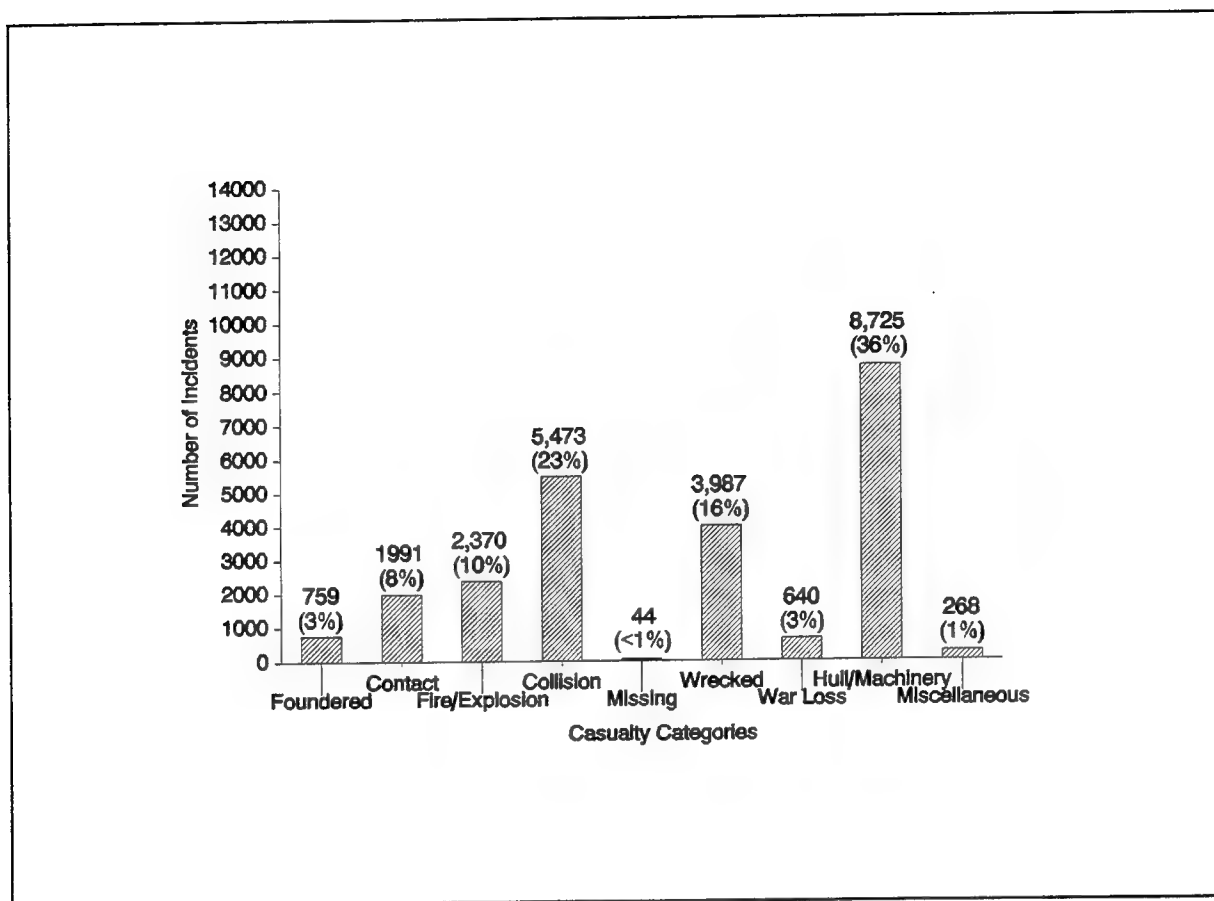


Figure 2-3

Number of Incidents by Casualty Category for All Vessels,  
1978-1992 (ships of 1,000 GT and over)

#### Summary:

Fire and explosion casualties on vessels  $\geq 1,000$  GT contribute to approximately 10% (or 2,370 incidents) of the overall casualty problem (24,257 incidents) of the world fleet. Approximately 10,000 casualty incidents were excluded by raising the vessel tonnage threshold to 1,000 GT. The relative frequency for casualty categories remained nearly constant. Foundering incidents reduced the most dramatically as a result of raising the tonnage threshold (a decrease of approximately 70%). Fire and explosion incidents ranked 4th in frequency below hull/machinery, collision, and wrecked categories.



Figure 2-4 summarizes the numbers of lives lost and persons missing reported as a result of all casualties for vessels  $\geq 1,000$  GT within the Lloyd's data base by casualty category.

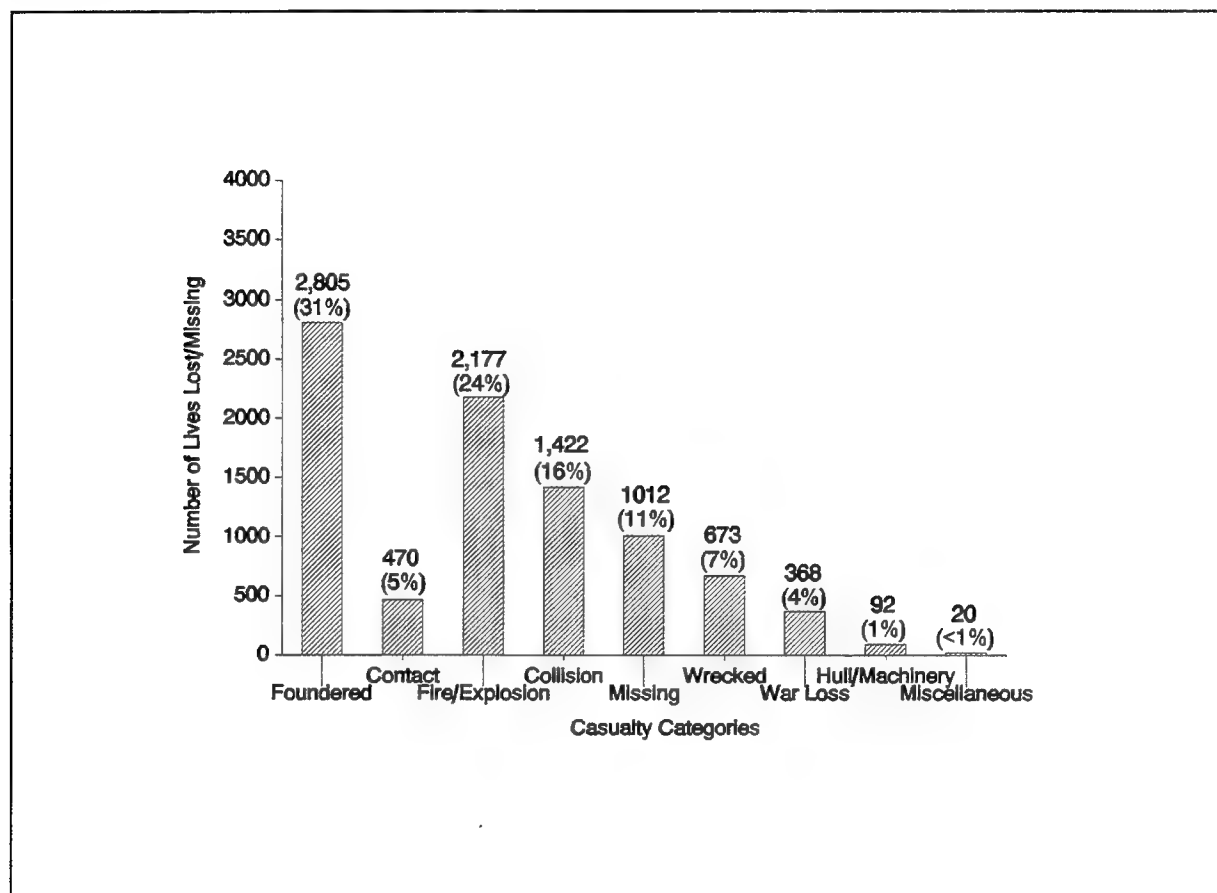


Figure 2-4

Lives Lost/Missing by Casualty Category for All Vessels,  
1978-1992 (ships of 1,000 GT and over)

#### Summary:

The numbers of lives lost/missing totals 8,858 persons as a result of 24,257 reported vessel casualty incidents (vessels  $\geq 1,000$  GT). This represents an average of 590 persons killed or missing per year.

[Note - this includes repair or new construction workers killed or missing as a result of vessel casualties.]

Fires and explosions are the 2nd leading cause of deaths based on the reported casualties. The assumption is made that persons reported as missing are considered lives lost.

Figure 2-5 summarizes the numbers of lives lost and persons missing as a result of fires or explosions sorted by vessel types.

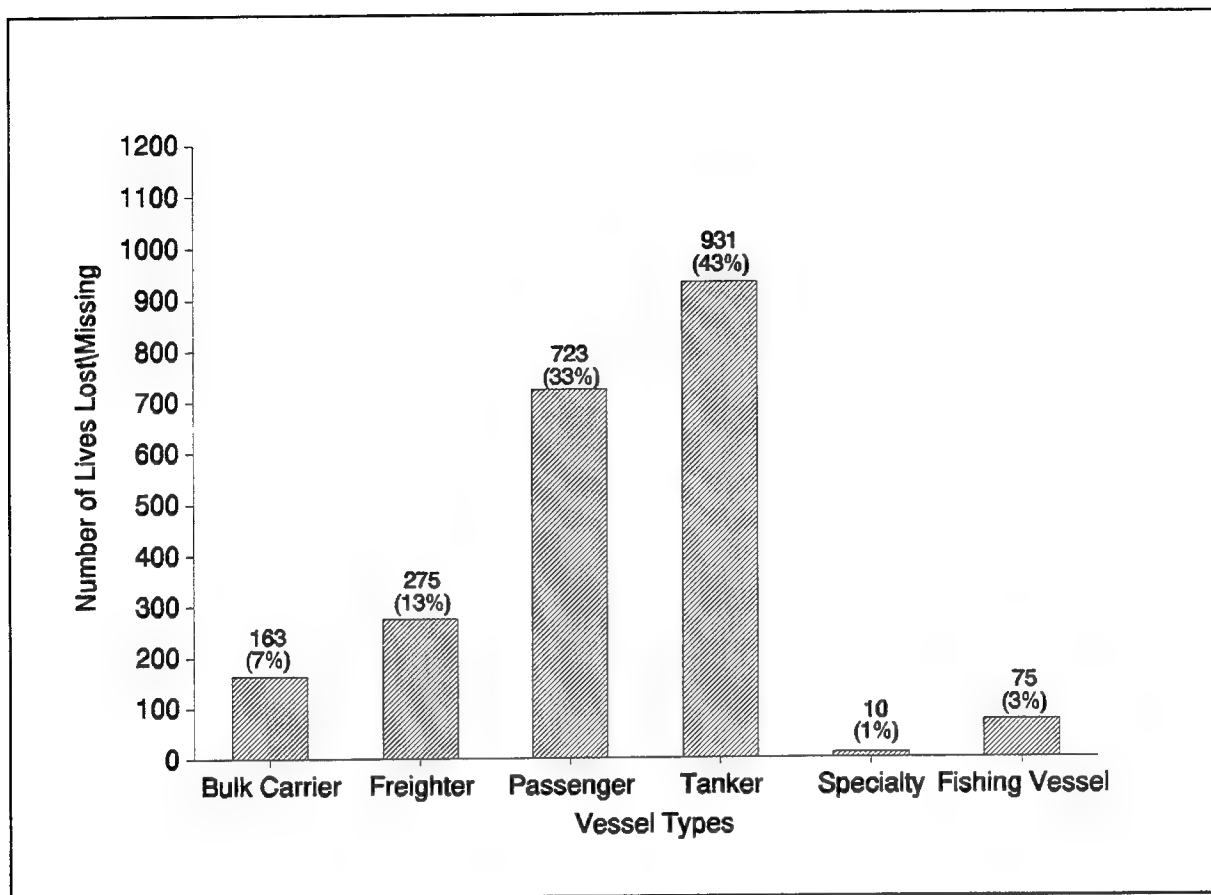


Figure 2-5

Lives Lost/Missing for all Fire/Explosion Casualties by Vessel Type, 1978-1992 (ships of 1,000 GT and over)

Summary:

Fire and explosion casualties have contributed to 2,049 persons killed or missing, the 2nd largest contributor of fatalities after the foundered casualty category. Tanker fire and explosion casualties contributed to the greatest numbers of lives lost/missing for a total number of 931 lives (or 43%), followed by passenger vessel fires and explosions with 723 lives (or 33%) for the 15-years of data.

Passenger vessels have the highest rate of persons killed or missing as a result of reported fires/explosions relative to fleet size. Passenger vessel fires/explosions resulted in 723 lives lost for the 15-year reporting period. Taking into account the mean fleet populations, the average number of deaths per vessel for passenger vessels is approximately 12 times that of tankers.

[Note - Based on the MARAD report, the tanker fleet population has remained relatively constant over the 11-year period (approximately 5,500 vessels), 1982 to 1992. The passenger fleet population decreased by 58 vessels (from 405 to 347 vessels).]

Figure 2-6 summarizes the final disposition of vessels involved in casualties, as a result of the casualty. Some of the casualty records did not have information on vessel disposition.

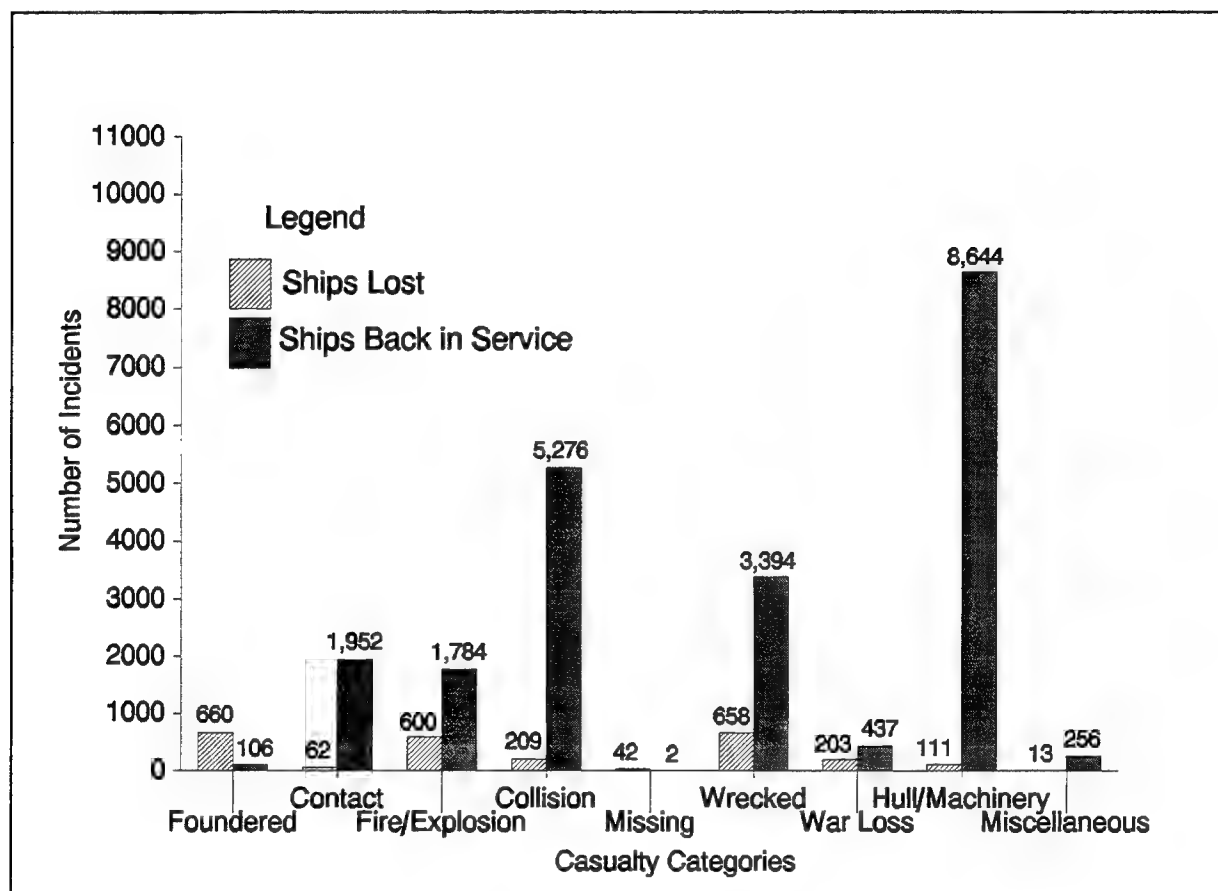


Figure 2-6

Reported Vessel Disposition by Casualty Category for All Vessels, 1978-1992 (ships of 1,000 GT and over)

Summary:

The following is the ranking of percentages of vessels lost compared to the number of casualties for each casualty category:

- Missing - 90% lost
- Foundered - 87% lost
- War loss - 32% lost

- Fire/explosion - 25% lost
- Wrecked - 17% lost
- Miscellaneous - 5% lost
- Collision - 4% lost
- Contact - 3% lost
- Hull/machinery - 1% lost

The overall total loss-to-casualty rate is 10%.

Fires and explosions have the 4th highest loss rate per casualty. Hull/machinery casualties have the most incidents, but also the highest rate of vessels back in service. This is a first level analysis only. A more detailed examination would include consideration of voluntary loss rates (i.e., vessel scrapping as a result of casualties) and would have to consider vessel age and condition to assess their influence on the decision to demolish the vessel.

Fires and explosions caused the 3rd highest number of vessel losses (600 vessels). Foundered (660 vessels) and wrecked (658 vessels) categories caused the highest number of vessels lost.

Figure 2-7 summarizes the 2,370 reported fire and explosion incidents by vessel types.

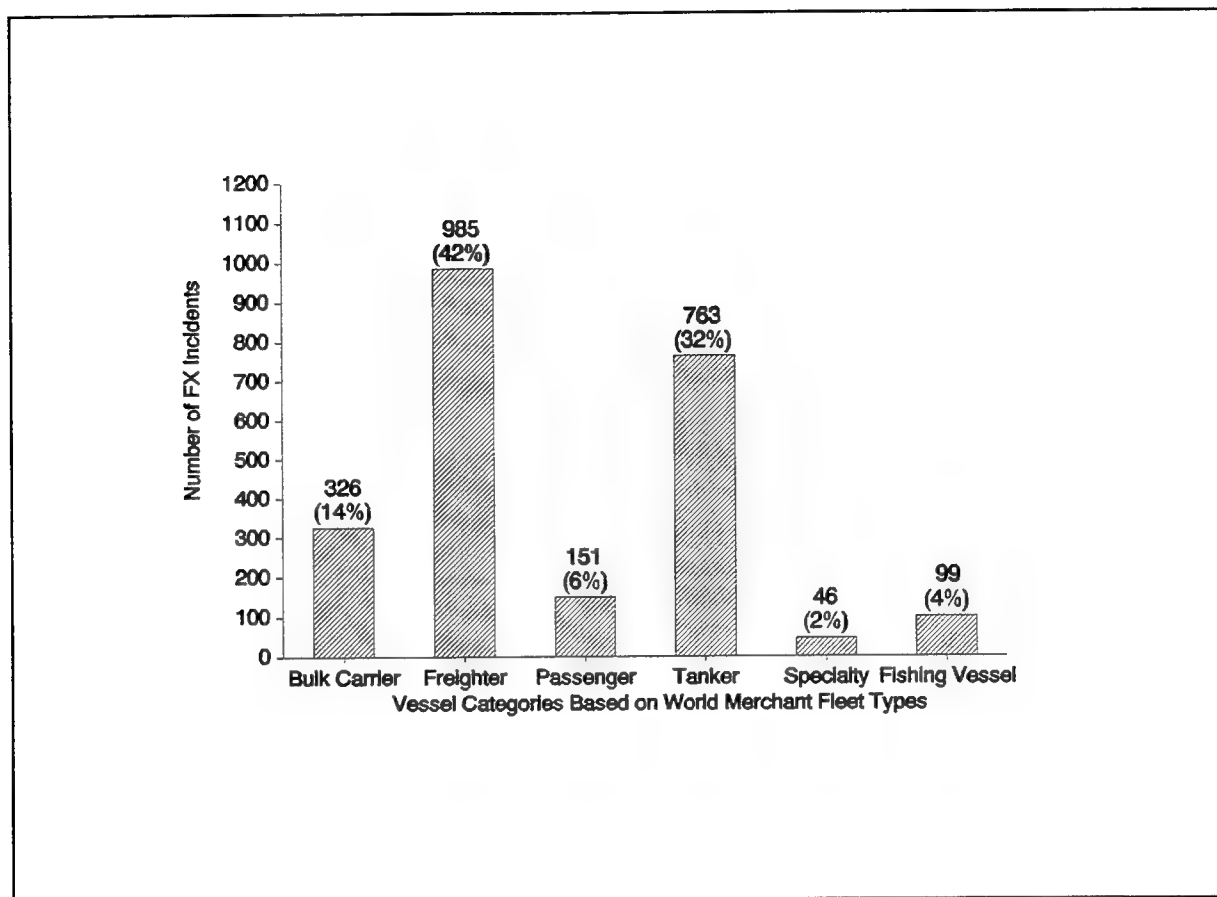


Figure 2-7

Fire/Explosion Casualties by Vessel Type,  
1978-1992 (ships of 1,000 GT and over)

Summary:

The passenger fleet has an average rate of 10 reported fire/explosion casualties per year based on the 15-year period. Using the mean fleet population of 376 vessels (based on 1982 and 1992 fleet sizes), this represents an average rate of 2.7% of the passenger fleet experiencing a fire/explosion in a given year.

The tanker fleet has an average rate of 51 reported fire/explosion casualties per year based on the 15-years of data. Using the mean fleet population of 5,530 vessels (based on 1982 and 1992 fleet sizes), this represents an average rate of 0.9% of the tanker fleet experiencing a fire/explosion in a given year.

The freighter fleet has an average rate of 66 reported fire/explosion casualties per year based on the 15-years of data. Using the mean fleet population of 13,391 vessels (based on 1982 and 1992 fleet sizes), this represents an average rate of 0.5% of the freighter fleet experiencing a fire/explosion in a given year.

The bulk carrier fleet has an average rate of 22 reported fire/explosion casualties per year based on the 15-years of data. Using the mean fleet population of 5,230 vessels (based on 1982 and 1992 fleet sizes), this represents an average rate of 0.4% of the bulk carrier fleet experience a fire/explosion in a given year.

Figure 2-8 is a yearly plotting of the reported fire and explosion incidents for all vessel categories.

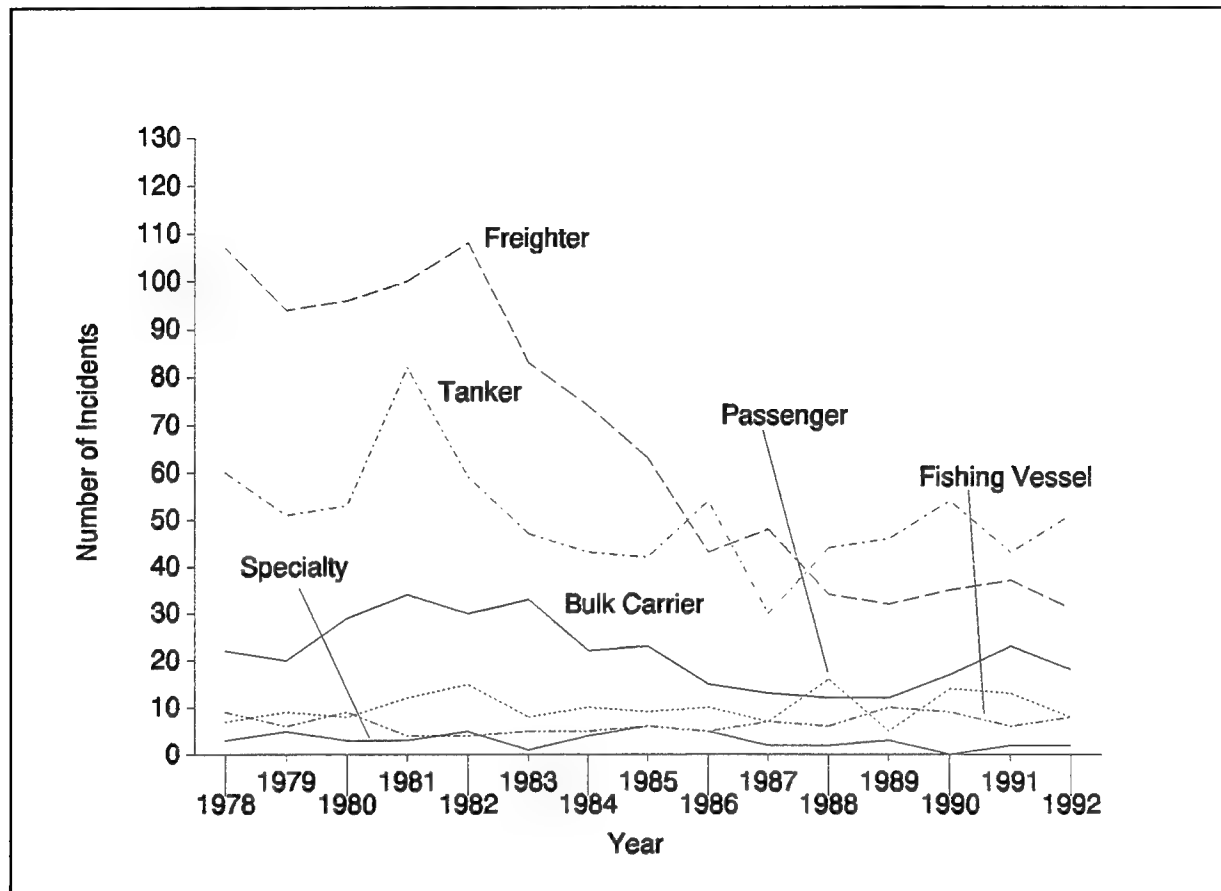


Figure 2-8

All Fire/Explosion Incidents by Vessel Type, 1978-1992  
(ships of 1,000 GT and over)

#### Summary:

The number of reported fires and explosions on freighters have decreased substantially since 1978, from approximately 100 incidents per year to approximately 35 incidents per year.

The noticeable drop in tanker fire/explosion casualties in the early 1980s may be attributable to regulations imposing inert gas systems.

The number of incidents reported on bulk carriers remains relatively constant at approximately 20 per year, with a slight decrease.

Passenger, fishing and specialty vessels all average at 10 incidents or below, per year (ships of 1,000 GT, and above).

## 2.3 SUMMARY OF SECTION 2.0 FINDINGS

### Composition of World Merchant Fleet (1992, $\geq 1,000$ GT)

- Bulk Carriers 5,473
- Freighters 12,581
- Passenger Vessels 347
- Tankers 5,542

### Fire and Explosion Problem

- Fires and explosions resulted in 3,299 incidents over the 15-year reporting period, or 10% of all reported casualty causes. The fire/explosion category represents the 4th most frequent contributor of casualties to all vessels  $\geq 100$  GT.
- Fire and explosion casualties on vessels  $\geq 1,000$  GT contributed to approximately 10% (or 2,370 incidents) of all casualties (24,257 incidents) to the world fleet. Again, fire/explosion incidents ranked 4th in frequency following hull/machinery, collision, and wrecked casualty categories, respectively.
- The passenger fleet has an average of 10 reported fire/explosion casualties per year based on the 15-years of data. Using the mean fleet population of 376 vessels, this represents an average rate of 2.7% of the passenger fleet experiencing a fire/explosion in a given year. (remaining relatively constant over the reporting period).
- The tanker fleet has an average of 51 reported fire/explosion casualties per year based on the 15-years of data. Using the mean fleet population of 5,530 vessels, this represents an average rate of 0.9% of the tanker fleet experiencing a fire/explosion in a given year. Fire/explosion casualties appear to have decreased slightly over the 15-year period (decreasing from an average rate of approximately 60 incidents per year to 50 per year).
- The freighter fleet has an average of 66 reported fire/explosion casualties per year based on the 15-years of data. Using the mean fleet population of 13,391 vessels, this represents an average rate of 0.5% of the freighter fleet experiencing a fire/explosion in a given year. Fire/explosion casualties for freighters has decreased substantially over the 15-year period (decreasing from an average rate of approximately 100 incidents per year to 35 per year).



- The bulk carrier fleet has an average of 22 reported fire/explosion casualties per year based on the 15-years of data. Using the mean fleet population of 5,230 vessels, this represents an average rate of 0.4% of the bulk carrier fleet experiencing a fire/explosion in a given year. Fire/explosion casualties for bulk carriers has decreased slightly over the 15-year period (decreasing from an average rate of approximately 30 incidents per year to 20 per year).

#### Lives Lost/Missing

- The numbers of lives lost/missing total 8,858 persons as a result of the 24,257 reported vessel casualty incidents. This represents an average of 590 persons killed or missing per year during the 15-year reporting period.

[Note - this includes repair or new construction workers killed or missing as a result of vessel casualties.]

- Fire and explosion casualties have contributed to 2,049 persons killed or missing, the second largest contributor after the foundered casualty category.
- Tanker fire/explosion casualties contributed to the greatest numbers of lives lost/missing for a total number of 931 lives (or 43%), followed by passenger vessel fires/explosions resulting in 723 persons killed or missing (or 33%) for the 15-year reporting period.
- Passenger vessels have the highest number of persons killed or missing as a result of reported fires/explosions relative to fleet population. Passenger vessel fires/explosions resulted in 723 persons killed or missing for the 15-year reporting period. Taking into account the fleet populations, the average number of deaths per vessel for passenger vessels is approximately 12 times that of tankers.

#### Vessels Lost

- Fires and explosions caused the 3rd highest number of vessel losses (600 vessels). Foundered (660 vessels) and wrecked (658 vessels) casualty categories caused the highest number of vessels lost.

### 3.0 ANALYSIS OF WORLD WIDE CASUALTIES INVOLVING FIRES/EXPLOSIONS AND MARINE POLLUTION

#### 3.1 OVERVIEW OF MARINE POLLUTION PROBLEM

The focus of this portion of the analysis was on presenting the overall marine pollution problem by all casualty categories and vessel types. The purpose of this section was to look at how fires/explosions related to the overall reported marine pollution problem and to determine which types of vessels had the greatest numbers of reported spill incidents.

Figure 3-1 summarizes all casualties with reported pollution by casualty category.

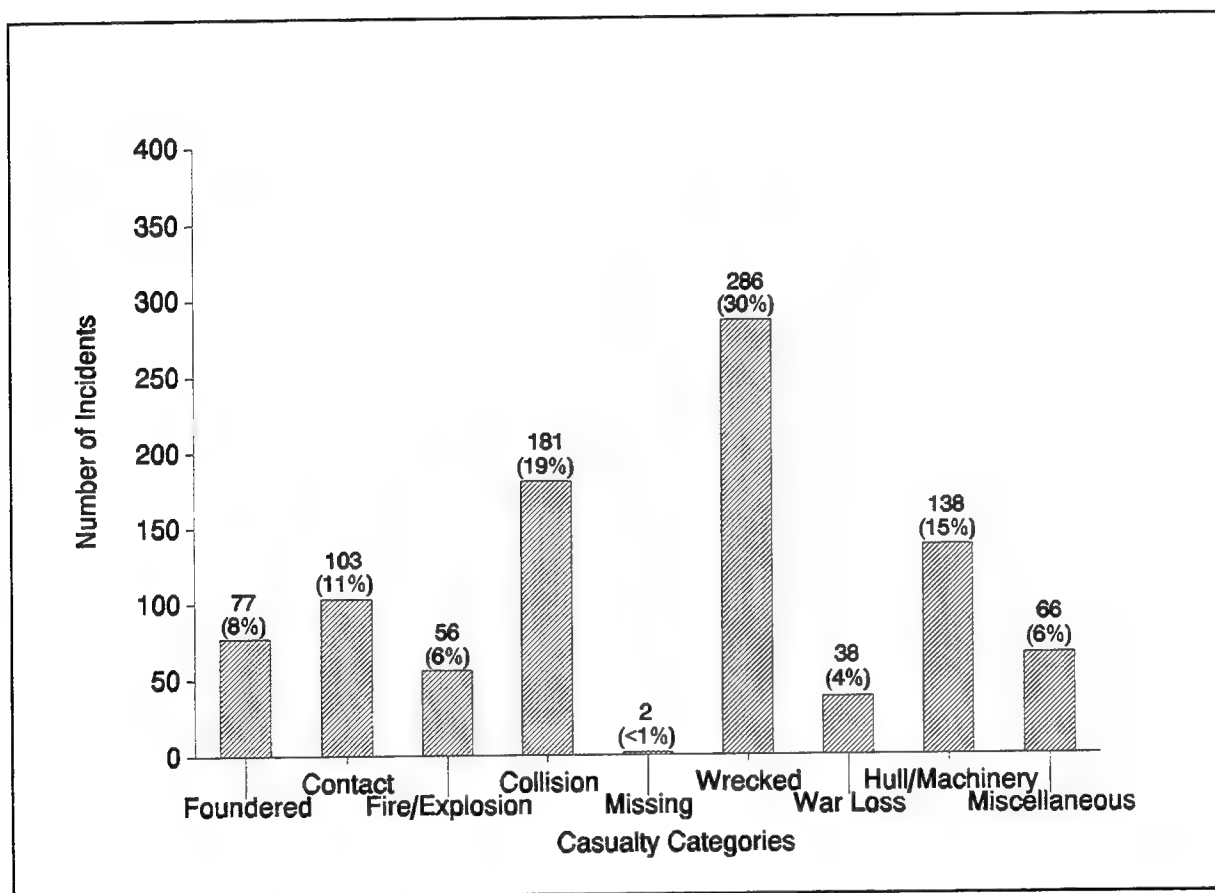


Figure 3-1

Number of Pollution Incidents by Casualty Category for All  
Vessels, 1978-1992 (ships of 1,000 GT and over)

There were 947 vessel casualties reported resulting in marine pollution. Of these, fires/explosions resulting in pollution totalled 56 incidents, ranking 7th out of the nine casualty categories. Fires/explosions contributed to 6% of the reported incidents, below wrecked, collisions, hull/machinery, contact, foundered, and miscellaneous, respectively.

Figure 3-2 shows how pollution associated with vessel casualties was reported in the Lloyd's data base. This is included to illustrate that most of the casualties are reported with either "unknown" or "no" pollution. Also, referring to Figure 3-7, the "no" and "unknown" pollution data trend reversed over the reporting years 1984-1985.

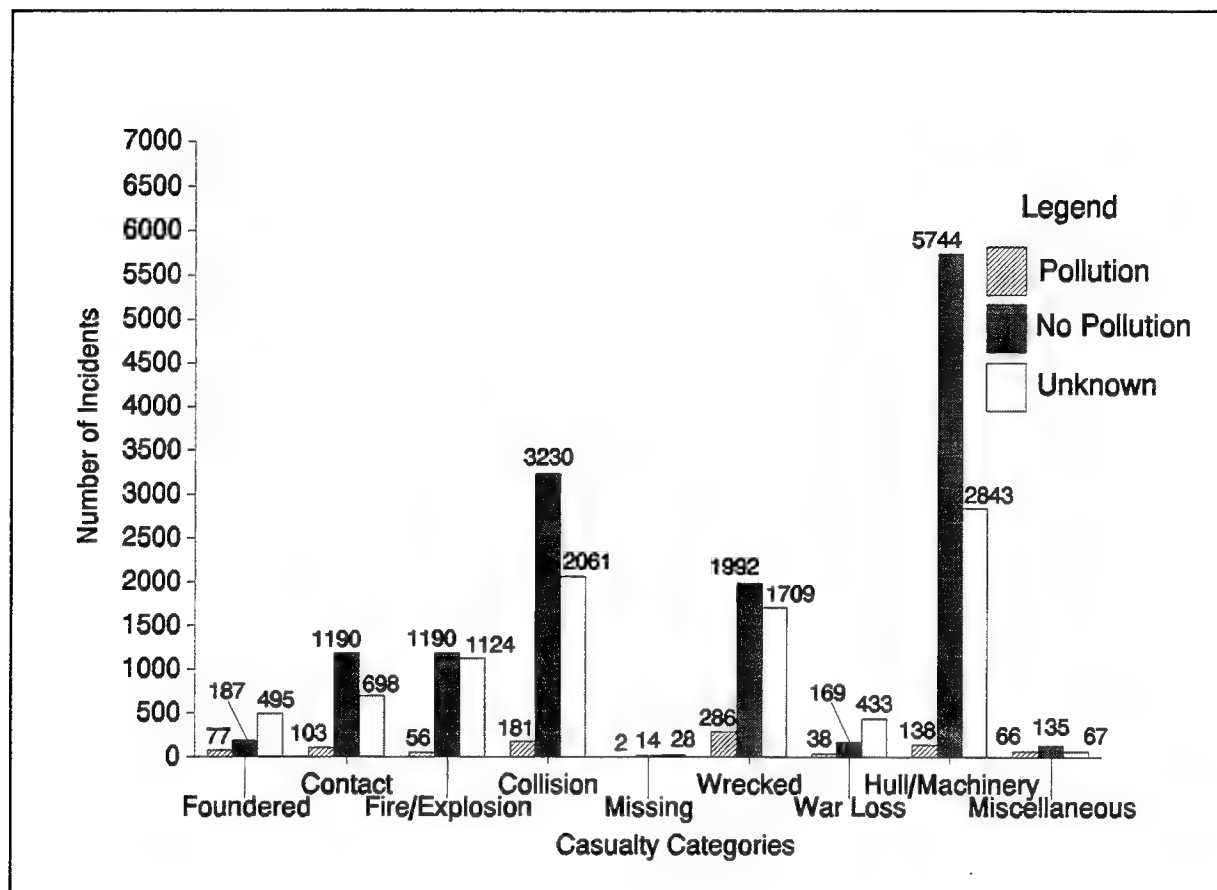


Figure 3-2

Reported Pollution Status with Respect to Casualty Category for All Vessels, 1978-1992 (ships of 1,000 GT and over)

#### Summary:

Based on the number of casualties reported with "unknown" pollution results along with the fact that the "no" and "unknown" reporting reversed during the years 1984-1985, the pollution problem is most likely worse than the data actually suggests. (For example, of the 43 tankers which sank as a result of fire/explosion casualties, only 21 were reported with associated pollution). The first approach to this study, however, is to report on the incidents with positive reported pollution.

Figure 3-3 summarizes the 947 reported marine pollution spills as a result of all casualty incidents with respect to the vessel type.

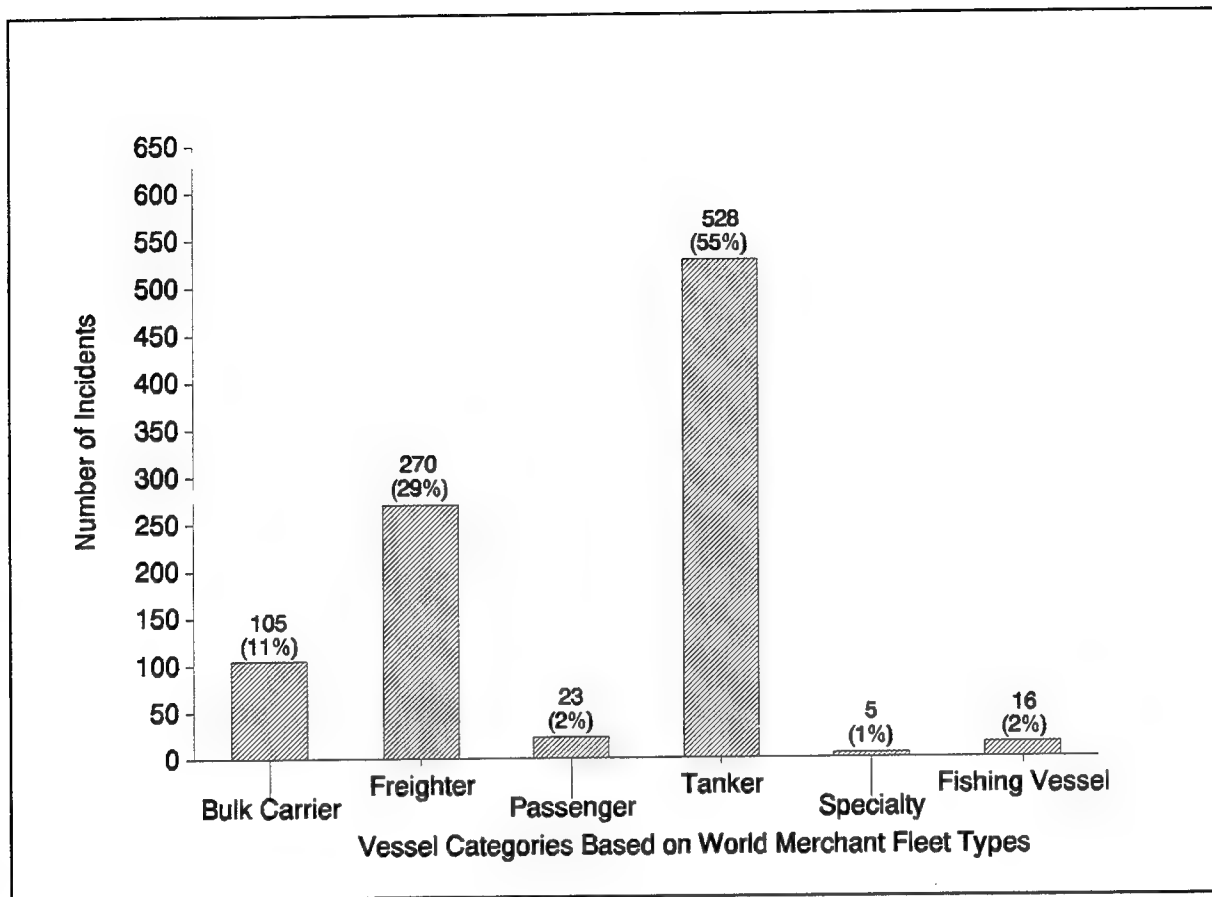


Figure 3-3

Number of Pollution Incidents for All Casualties by Vessel Type, 1978-1992 (ships of 1,000 GT and over)

Summary:

This figure shows that the tanker fleet is the largest contributor to the reported marine pollution problem. The freighter fleet is the 2nd largest contributor in terms of numbers of incidents. Considering the tanker fleet population, the tanker fleet experiences roughly four times the number of pollution incidents per vessel to that of the freighter fleet. The 528 reported tanker polluting casualties represent an average rate of 35 per year.

Figure 3-4 shows how pollution status was reported in the Lloyd's data base for all vessel categories. This format is similar to that of Figure 3-2. Again, this is included to illustrate that most of the casualties are reported with either "unknown" or "no" pollution.

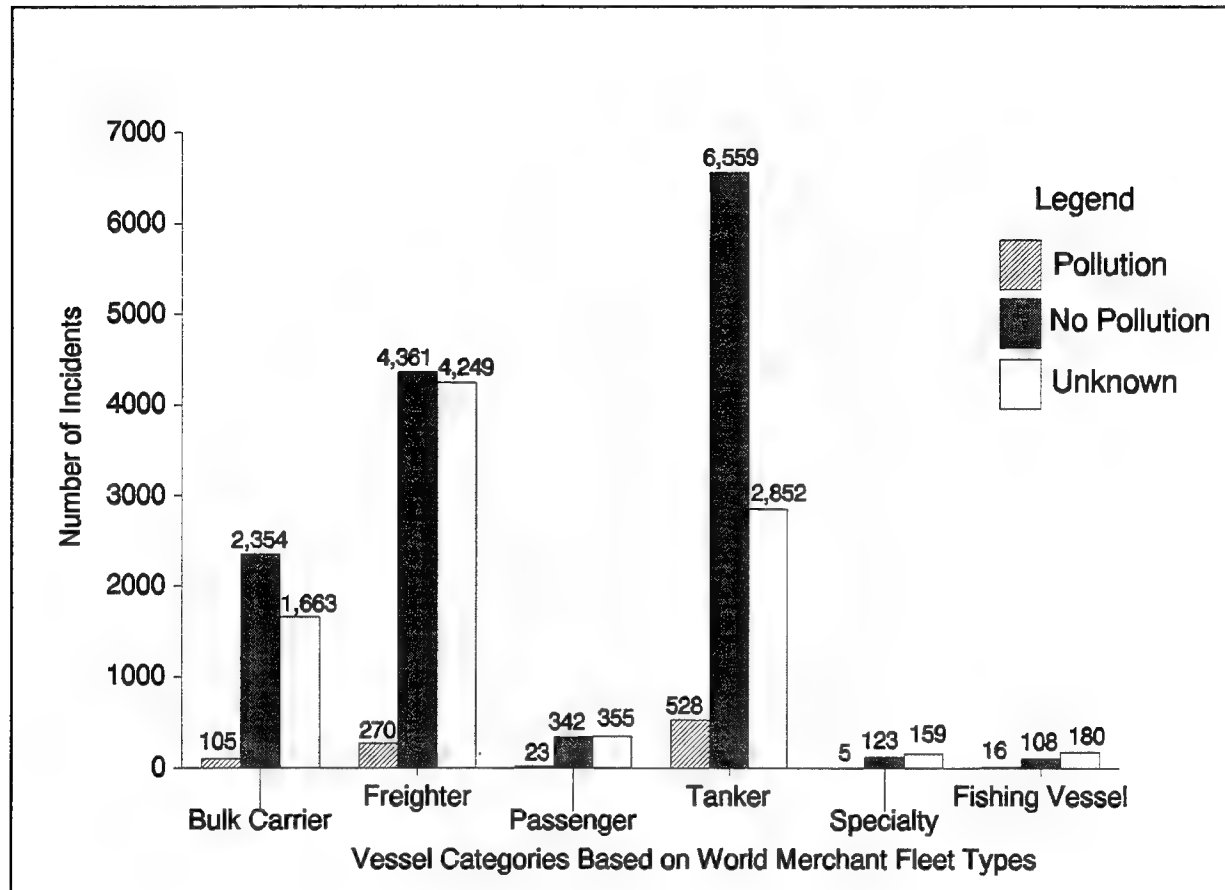


Figure 3-4

Reported Pollution Status for All Casualties by Vessel Type,  
1978-1992 (ships of 1,000 GT and over)

#### Summary:

Approximately 1/3rd of the tanker casualties are reported as "unknown" pollution. In addition, a portion of the reported "no" pollution data may also represent "unknown" pollution data due to the changes in the reporting trend. Refer to Figure 3-7 and the accompanying discussion.

### 3.2 FIRES/EXPLOSIONS RESULTING IN MARINE POLLUTION

The focus of this portion of the analysis was on fire/explosion casualties with reported marine pollution (this amounted to 56 cases). Analysis of this fire/explosion/pollution data showed that the tanker fleet is the greatest contributor to known pollution (41 cases). As presented in the figures to follow, freighters only reported seven (7) fire/explosion/pollution incidents. As a result of these findings, tanker casualty circumstances are presented and discussed in some detail in Sections 3.3 and 3.4.

Tanker fire/explosion casualty data with pollution reported as "unknown" and "no" were also analyzed in Section 3.4 because of the following:

- 1) By Lloyd's definition, the absence of reported pollution does not imply that "no" pollution occurred.
- 2) Analysis of the data on these 763 fire/explosion casualties could provide valuable insight into the tanker fire/explosion problem.
- 3) It was considered that there was potential for major pollution spills in many of these incidents.
- 4) When the three types of pollution responses were analyzed with respect to time, it was observed that the relative number of casualties reporting "no" pollution and "unknown" pollution reversed in the 1985-86 time period. This suggested that a shift in reporting policy occurred which resulted in more casualties being reported as "unknown" polluting incidents (refer to Figure 3-7).

The casualty data for the 41 and 763 tanker fire/explosion incidents were applied to spreadsheets and the text describing the incidents, generally composed of two to three sentences, were summarized for each. These summaries were further categorized to provide a less granular view of the common characteristics of the incidents than could be discerned from the coded information alone. This allowed some categorization of the causes of the casualties.

Figure 3-5 summarizes the fire/explosion casualties with respect to reported pollution by vessel types. The number of known pollution incidents among tanker fire/explosion casualties is the highest among the vessel types.

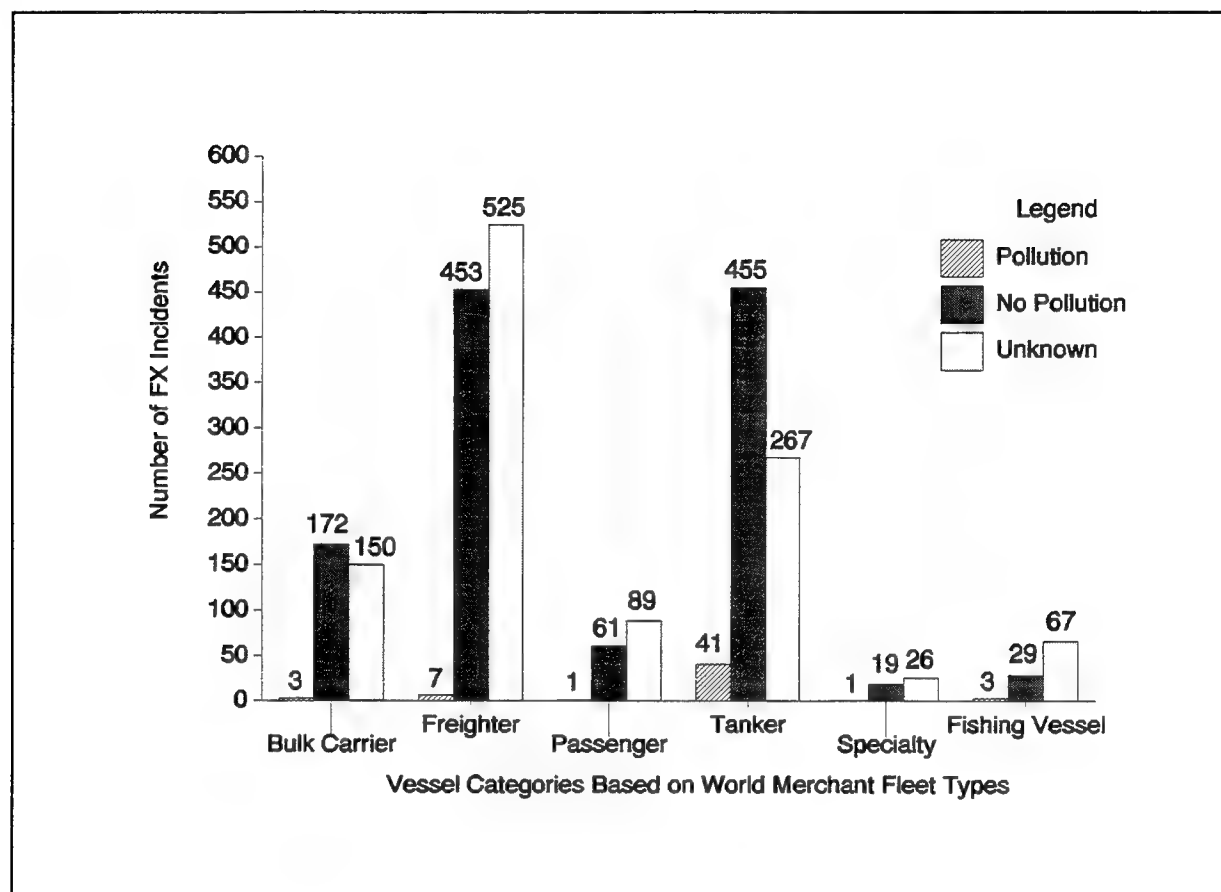


Figure 3-5

Fire/Explosion Casualties and Reported Pollution by Vessel Type, 1978-1992 (ships of 1,000 GT and over)

#### Summary:

There were a total of 56 marine pollution incidents as a result of fires/explosions. The majority of these pollution incidents were reported on tankers (41 incidents). For tankers, this is an average of 2.7 pollution incidents per year (15-year reporting period) and represents a fire/explosion/pollution incident rate of approximately 0.05% of the tanker fleet per year. The circumstances surrounding the fire/explosion and pollution event were generally not reported.

The source of pollution for these incidents are estimated as 30 cargo spills, 8 unknown, and 3 bunker spills. This estimate is based on examining information in the casualty records such as cargo status codes and text descriptions of the casualty. The volume of pollution, in many cases, was not reported.

Figure 3-6 summarizes all reported pollution incidents on tankers as a result of all casualty types. There are a total of 528 reported pollution events.

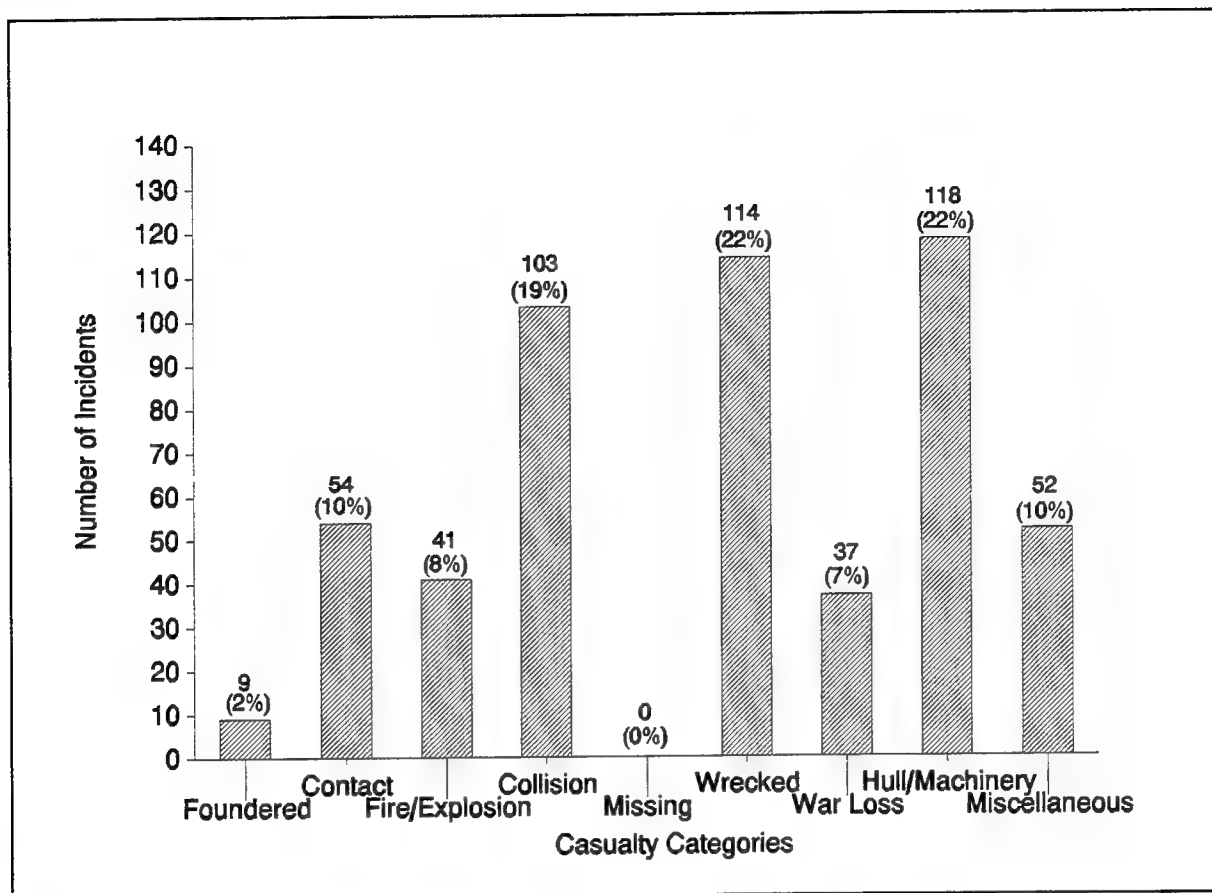


Figure 3-6

Number of Pollution Incidents by Casualty Category for Tankers,  
1978-1992 (Tankers of 1,000 GT and over)

Summary:

Of the 41 tanker fire/explosion/pollution incidents, 39 casualties were reported to be in the "serious" category. Fire/explosion casualties contributed to 8% of all tanker pollution incidents and rank 6th in frequency behind hull/machinery, wrecked, collisions, contact, and miscellaneous, respectively.



Figure 3-7 represents the reporting of tanker fire/explosion/pollution incidents by year. The pollution line represents an average of 2.7 incidents per year. With respect to the "no" and "unknown" pollution data, this figure suggests that the rationale for reporting pollution status changed during the years 1985 through 1986.

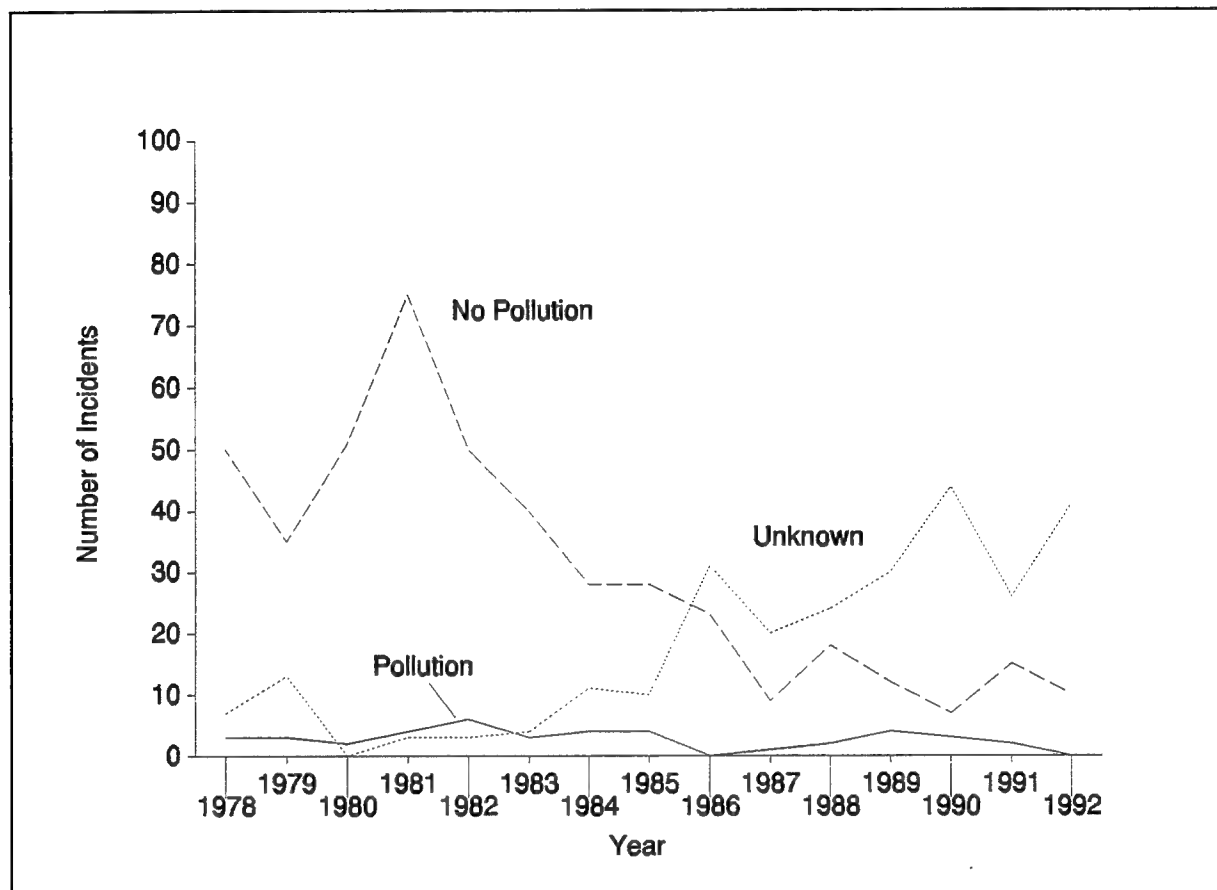


Figure 3-7

Number of Tanker Fire/Explosion Incidents by Reported Pollution Status (ships of 1,000 gross tons and over)

#### Summary:

This figure illustrates that most of the casualty incidents are reported as "no" or "unknown" with respect to pollution. As a result of this finding, the follow-on approach of this study was to include both the "no" and "unknown" pollution data in Section 3.4, and thereby consider all reported fire/explosion data on tankers.

### 3.3 TANKER FIRE/EXPLOSION/POLLUTION ANALYSIS

The analysis conducted in Sections 3.1 and 3.2 determined that the tanker fleet experienced the highest reported pollution incident rate among vessel types. There were a total of 528 reported pollution incidents for tankers as a result of all casualty categories reported, or an average of 35 pollution incidents per year, based on the 15-year reporting period.

Fires and explosions resulting in reported pollution contributed to 41 (or 8%) of these 528 tanker pollution incidents, ranking fires/explosions 6th among the 9 casualty categories. This averages to 2.7 tanker polluting incidents per year or approximately 0.05% (1/20th of 1%) of the tanker fleet experiencing a fire/explosion/polluting casualty in a given year. As a result, it was determined that the circumstances surrounding the tanker fleet casualty incidents should be studied. The first step was to examine the 41 tanker fire/explosion incidents with known pollution, exclusively. Next, the scope was widened to include all the reported tanker fire/explosion incidents for ocean-going tankers of 1,000 GT and above (763 incidents), regardless of the reported pollution status.

The Lloyd's data base contains reports of 41 fire/explosion incidents on tankers of 1,000 GT and over, which were reported to have caused pollution, for the period 1978 through 1992. Each record contains a short narrative regarding the incident which, in some cases, describes the circumstances of the casualty. We have summarized these remarks, when available, in order to try to detect trends or common elements among the casualties. The results are summarized in Table 3-1 on the following page.

Approximately half of the circumstances surrounding these fire/explosion/pollution incidents are reported as "unknown". Of the other 20 casualties - hull failures, hot work, leaks/spills and lightning strikes were involved in multiple incidents within this limited data group. In some of these circumstances weather was a factor. It is difficult to make any conclusions based on this limited data and the limited descriptions of the events contained in the casualty data. As a result, part of the rationale for reviewing the 763 fire/explosion data records for tankers in Section 3.4 was to further attempt to identify common factors surrounding the fire/explosion casualty incidents on tankers.

Table 3-1

Summary of Circumstances of the 41 Reported Tanker Polluting  
Fire/Explosion Incidents

Circumstances	No. of Incidents	Comments
Hull Crack or break	4	
Hot work or hot object	3	2 incidents due to hot work; 1 due to hot object falling from overhead bridge structure.
Leak or spill	4	
Lightning strike	3	All three vessels were in port.
Main engine problem	1	
Electrical switchboard problem	1	
Operating procedure	1	
Spark ignition	1	Reported cause was sparks from anchor
Unknown or not reported	23	

Figure 3-8 presents the location of the fire/explosion/pollution incidents reported for the 41 tanker incidents with reported pollution.

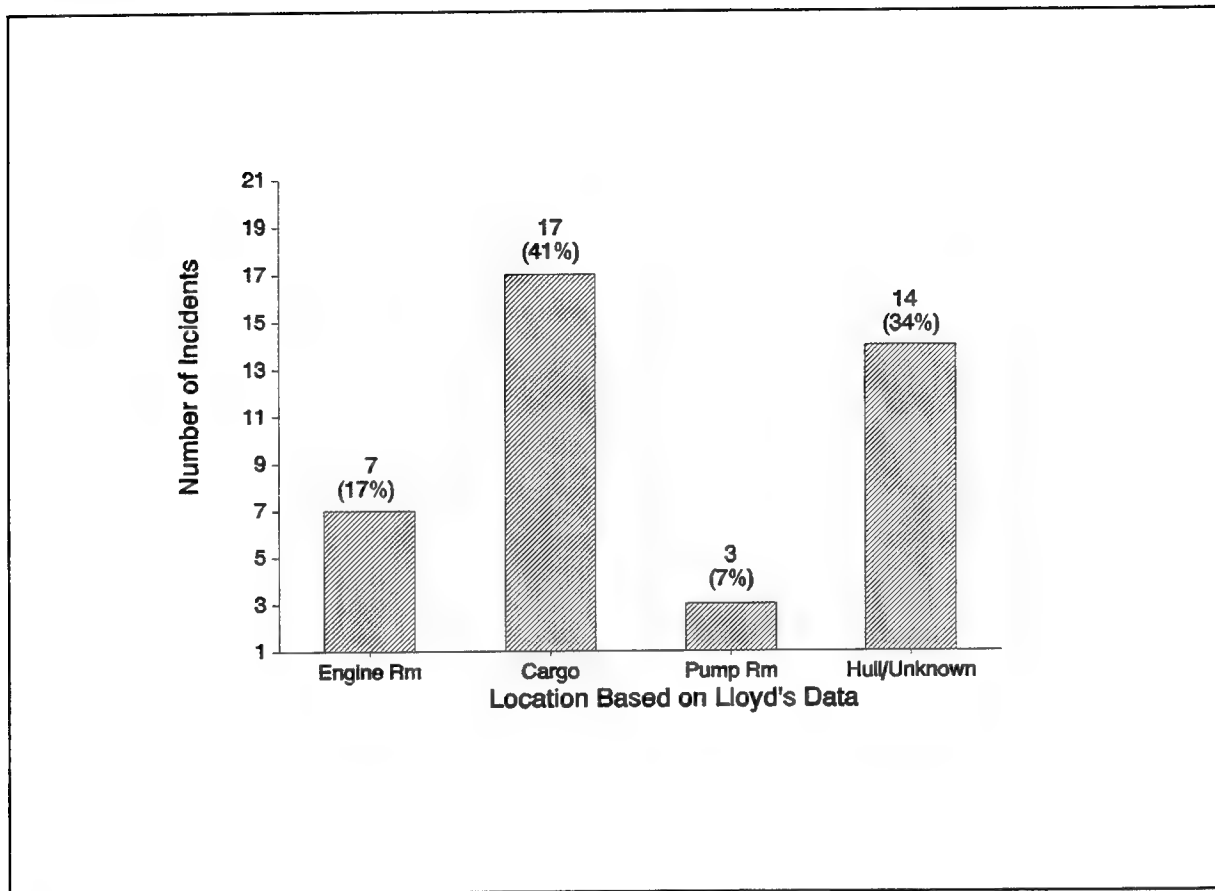


Figure 3-8

Location of Polluting Fire/Explosion Incidents on Tankers,  
1978-1992 (ships of 1,000 GT and over)

Summary:

The most frequent site of the fire/explosion/pollution casualties presented in Figure 3-8 was in the area of the cargo tanks, for a total of 17 incidents (or 41%). Seven (7) of the fire/explosion/pollution incidents were reported to occur in the engine rooms (or 17%), and fourteen (14) of the incidents location were hull/unknown (or 34%).

[Note - Hull/unknown is a compartment code that is used frequently in the casualty event records. Based on the descriptive text contained in the records, it appears that hull/unknown is synonymous with unknown.]

Figure 3-9 presents the reported status of the tankers at the time of the polluting fire/explosion incident.

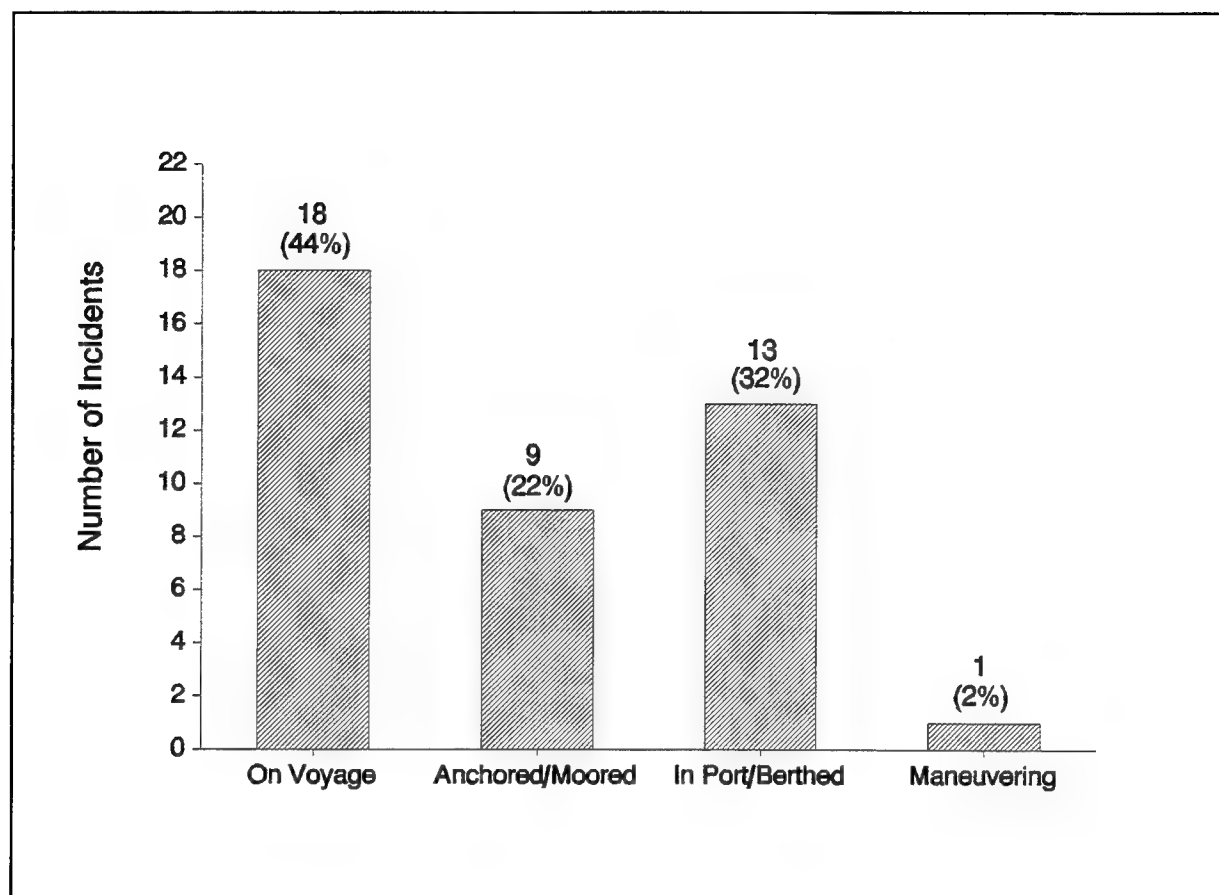


Figure 3-9

Status of Tanker at Time of Polluting Fire/Explosion Incidents, 1978-1992 (ships of 1,000 GT and over)

Summary:

Approximately half of the incidents occurred while the vessel was at sea and the other half while the vessel was either at anchor or in port. This suggests that there is more of a problem with these incidents occurring while the vessel is in port or relatively close to shore since tankers typically minimize their in-port/at-anchor time to spend the majority of their operational time in the business of transporting cargo at sea.

Figure 3-10 presents the tankers cargo status at the time of the reported fire/explosion/pollution incident.

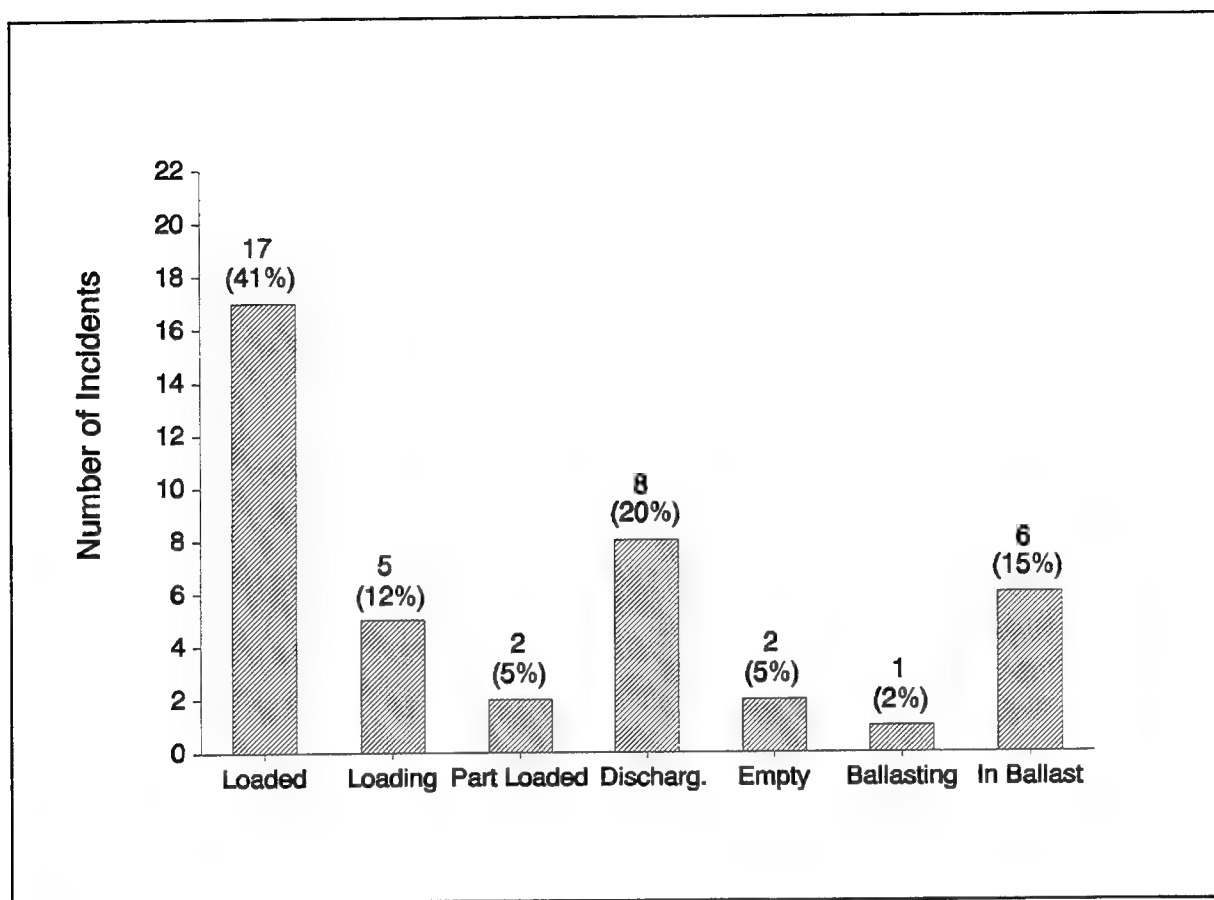


Figure 3-10

Cargo Status for Polluting Fire/Explosion Incidents on Tankers,  
1978-1992 (ships of 1,000 GT and over)

Summary:

The majority of the incidents (19) occurred to tankers that were in a loaded or partly-loaded condition, representing a total of 46% of the incidents. Thirty-two percent or (13) incidents occurred while the tankers were loading or unloading cargo. Twenty-two percent or (9) of the vessels were either reported as empty, in-ballast, or ballasting status.

Figure 3-11 presents the ages of the tankers at the time of the fire/explosion/polluting incidents. This assessment was conducted to determine if there was any obvious concentration of incidents with respect to the age of the vessels.

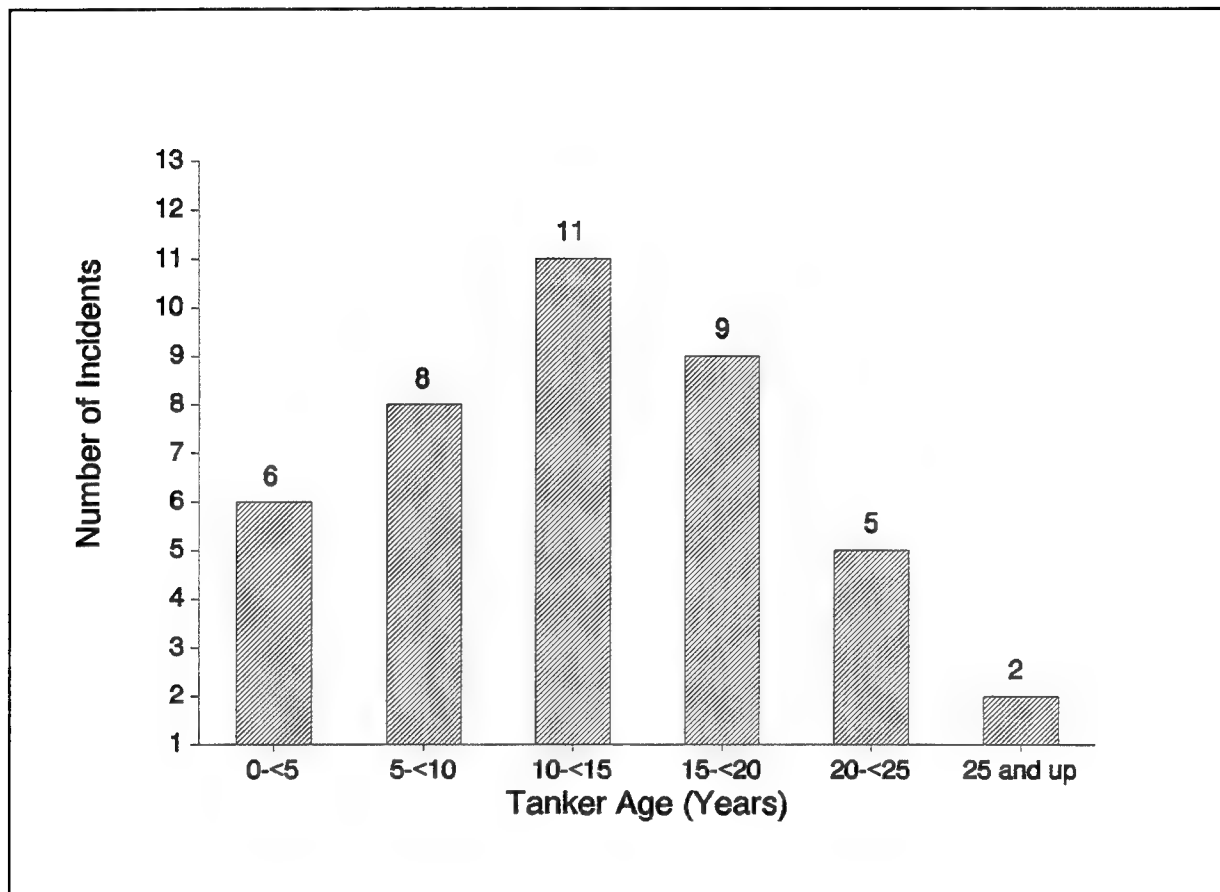


Figure 3-11

Age of Tanker at Time of Polluting Fire/Explosion Incidents,  
1978-1992 (ships of 1,000 Gross Tons and over)

Summary:

The data for the 41 fire/explosion/polluting incidents demonstrates that this problem is not inherent to any particular vessel age group. Based on these limited data records, the vessels in the 20 year age grouping and beyond had the lowest reporting rate.

[Note - This data is not normalized with respect to the age groupings of the tanker fleet. In follow-up conversation with MARAD, this tanker age grouping data was not available.]

### 3.4 TANKER FIRE/EXPLOSION ANALYSIS

There are 763 fire/explosion casualties contained within the Lloyd's Casualty Information System data base for tankers of 1,000 GT and over for the period 1978 through 1992. (refer to Figure 2-7.) The rationale for expanding this fire/explosion/pollution analysis to include these 763 fire/explosion data records was described in Section 3.2. The same approach used for Section 3.2 is followed for this expanded data analysis.

Figure 3-12 presents the location of the fire/explosion incidents reported for the 763 tanker casualties.

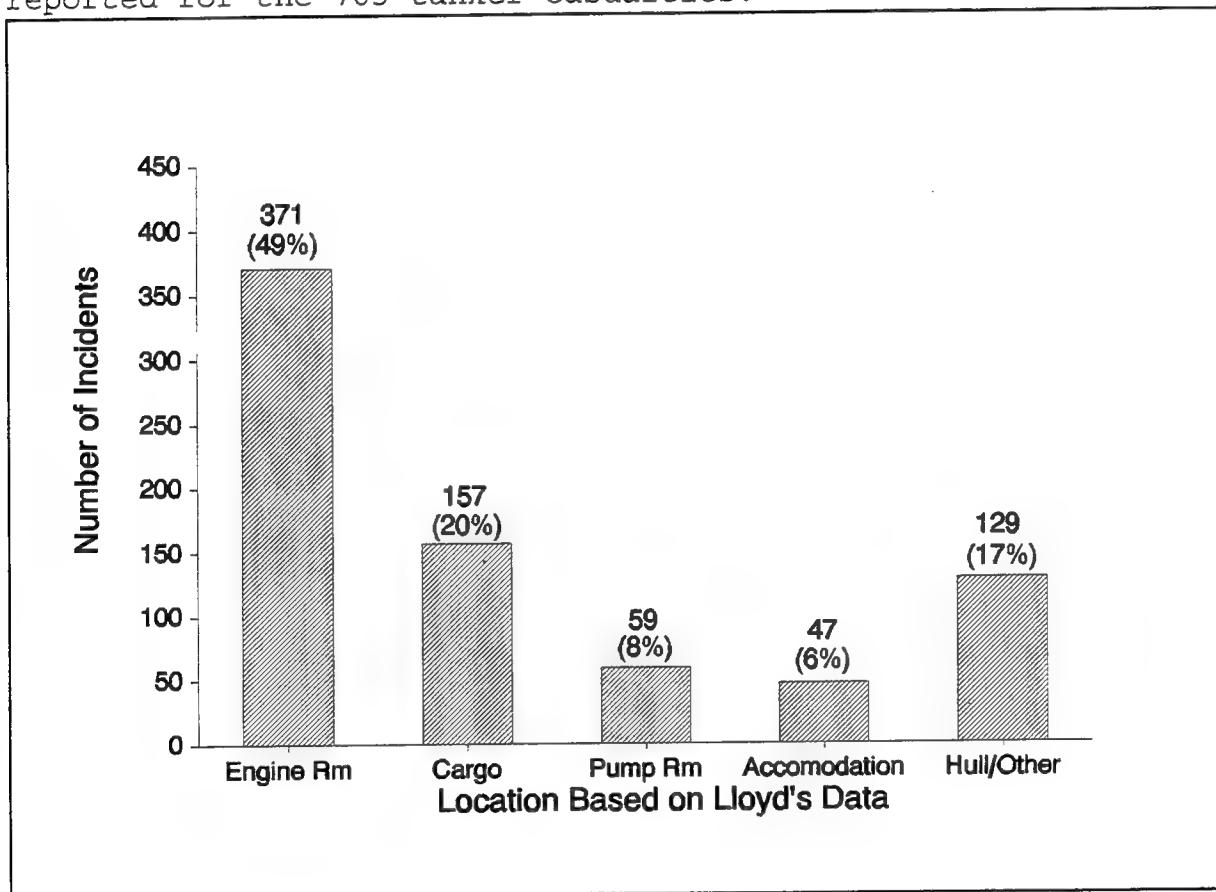


Figure 3-12

Location of Fire/Explosion Incidents on Tankers,  
1978-1992 (ships of 1,000 Gross Tons and over)

#### Summary:

The majority of the fires and explosions were reported to occur in the engine rooms (371 incidents) or 49%. One hundred and fifty seven fire/explosion casualties occurred in the cargo tank areas or 20%. The remainder of the incidents were spread among hull/unknown/other, pump rooms and accommodation spaces. The casualty data is examined in more detail with respect to location in the following tables.



Table 3-2 presents a summary of the circumstances surrounding the available details of all the tanker fire/explosion incidents with respect to the reported locations and/or equipment involved.

Table 3-2  
Location of Tanker Fire/Explosion Incidents

Location of Fire/Explosion	No. of Incidents	No. of "Serious" Incidents	Incidents with Reported Pollution	Persons Killed/Missing
Tankers	763	373	41	929
Accommodation	47	25	0	61
Cargo	157	86	17	382
Engine room	371	191	7	204
Pump/Pump Room	59	14	3	34
Hull/Unknown/Other	129	57	14	248

Summary:

The majority of the 763 fire/explosion incident reports included some information on the locations and equipment involved in the casualty. Approximately half of the circumstances surrounding these fire/explosion incidents on tankers were reported to occur in the engine rooms (48%). Approximately, 20% of the incidents occurred in the cargo areas, and 17% occurred in hull/unknown/other category. The accommodation and pump room locations were each below (10%). In contrast, for the 41 fire/explosion/pollution incidents reported in Section 3.3, the majority of those incidents were found to occur in the area of the cargo tanks (or 41%), and 20% were reported to occur in the engine rooms.

Table 3-3 presents more details of the circumstances surrounding the 371 reported engine room fire/explosion incidents.

Table 3-3

Circumstances of Tanker Engine Room Fire/Explosion Incidents

Location of Fire/Explosion	No. of Incidents	No. of "Serious" Incidents	Incidents with Reported Pollution	Persons Killed/Missing
Engine room	371	191	7	204
Boiler	68	47	0	15
Electrical	33	17	1	0
Electrical-Switchboards	25	9	1	0
Electrical-Other	8	8	0	0
Engines	53	17	1	4
Engine-Crankcase	13	5	0	0
Engine-Exhaust	12	4	0	0
Engine-Scavenge	11	3	0	0
Engine-Other	17	5	1	4
Generators	9	3	0	0
Leak/Spill	17	12	1	1
Hot Work/Under Repair	28	16	1	105
Engine room-Other/Unknown	163	79	3	79

Summary:

Of the 371 engine room fires/explosions reported, 51% of them were categorized as "serious" in nature. Very few of the engine room incidents were reported to cause pollution. The majority of "serious" incidents were associated with the boilers and main engines. The majority of people killed were associated with hot work/under repair. 36 of the 371 engine room fire/explosion casualties (or 10%) involved fatalities. In 87% of the 371 incidents, the vessel was repaired and returned to service.

Table 3-4 presents more details of the circumstances surrounding the 157 reported cargo space area fire/explosion incidents.

Table 3-4

Circumstances of Tanker Cargo Space Fire/Explosion Incidents

Location of Fire/Explosion	No. of Incidents	No. of "Serious" Incidents	Incidents with Reported Pollution	Persons Killed/Missing
Cargo	157	86	17	382
Lightning	4	3	3	18
Tank Cleaning	16	16	0	68
Hot Work	14	8	1	55
Under Repair	54	11	0	63
Unknown/Other	69	48	13	178

Summary:

There were 157 fires/explosions reported to occur in the cargo space areas, representing approximately 20% of the 763 total reported fires/explosions on tankers. Not considering the incidents which occurred in the "unknown/other" circumstances, repair or hot work activities were taking place at the time of 68 out of the remaining 88 incidents. Seventy-nine of the 157 incidents (or 50%) involved fatalities.

Table 3-5 presents more details of the circumstances surrounding the 47 reported accommodation space area fire/explosion incidents.

Table 3-5

Circumstances of Tanker Accommodation Space  
Fire/Explosion Incidents

Location of Fire/Explosion	No. of Incidents	No. of "Serious" Incidents	Incidents with Reported Pollution	Persons Killed/ Missing
Accommodation	47	25	0	61
Under Repair or Construction	6	3	0	3
Electrical	5	2	0	1
Unknown/Other	36	20	0	57

Summary:

Twenty-three percent of these 47 accommodation space casualties involved fatalities and none of these casualties resulted in reported pollution. These accommodation space casualties account for 6% of all the reported tanker fire/explosion casualties.

Figure 3-13 presents the status of the tankers at the time of the reported fire/explosion incidents.

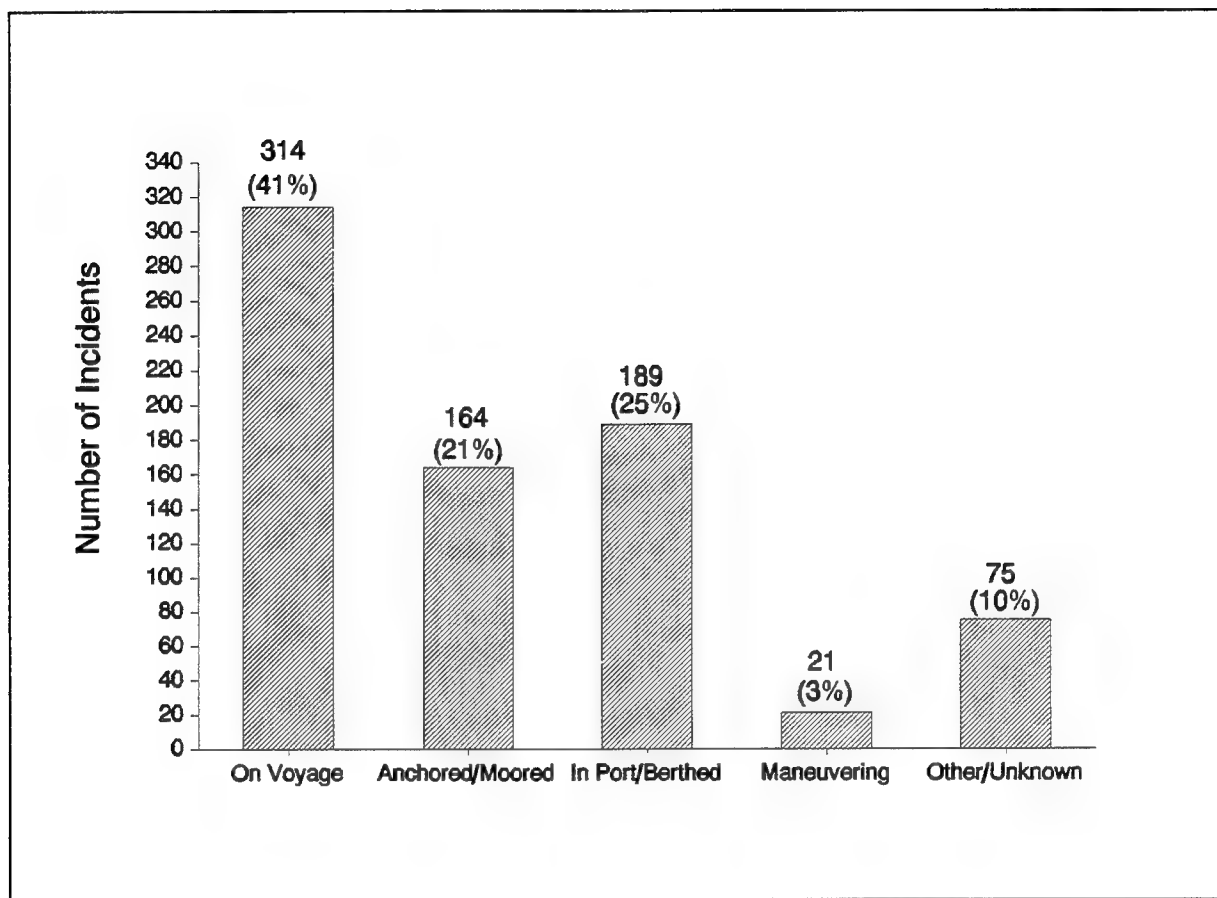


Figure 3-13

Navigation Status of Tanker at Time of Fire/Explosion Incidents,  
1978-1992 (ships of 1,000 GT and over)

Summary:

This tanker status summary for all fire/explosion incidents closely parallels the similar summary for the 41 reported polluting incidents. (refer to Figure 3-9.) For polluting incidents, 46% occurred while the vessel was on voyage or maneuvering.

Figure 3-14 presents the cargo status at the time of the reported fire/explosion incidents.

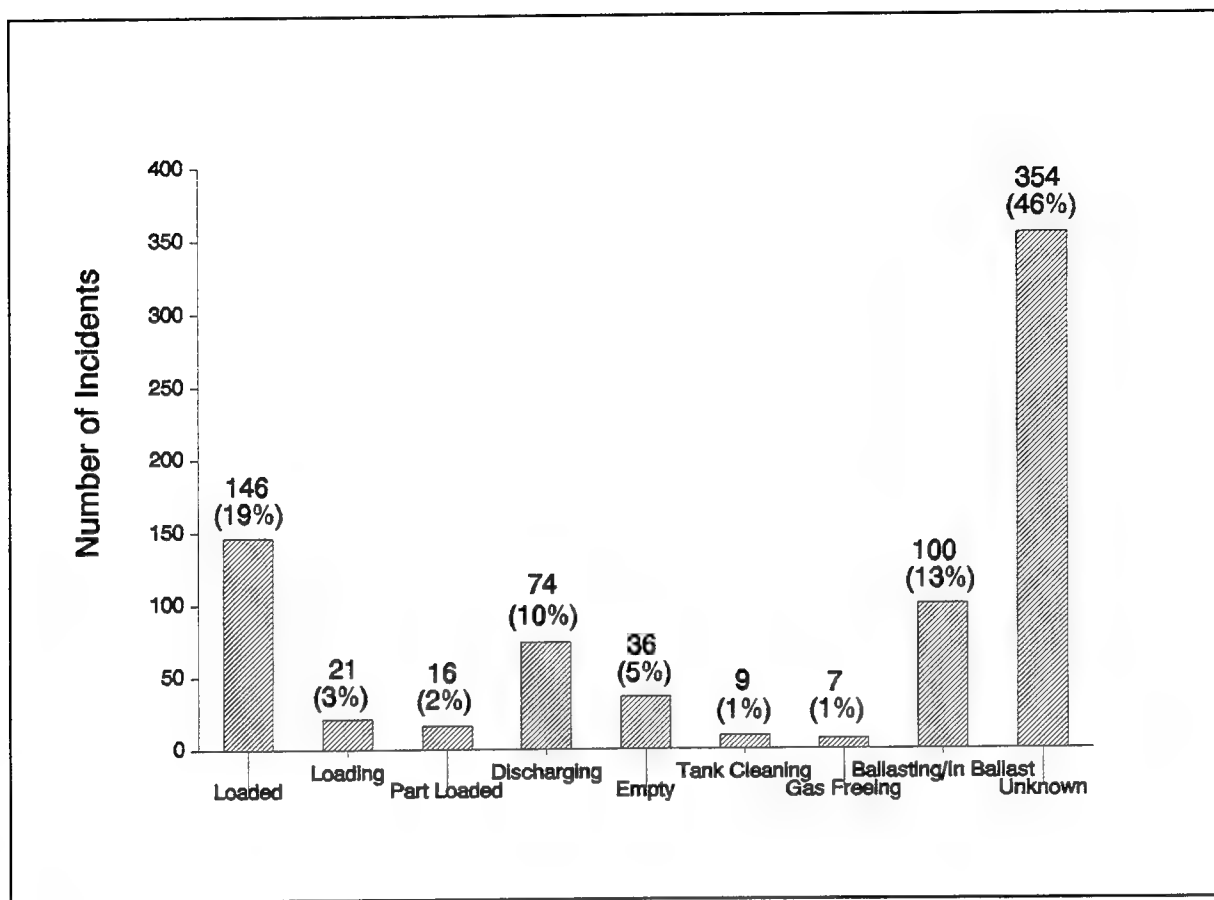


Figure 3-14

Cargo Status at Time of Fire/Explosion Incidents,  
1978-1992 (ships of 1,000 GT and over)

Summary:

If the large number of "unknown" reports of cargo status are not considered, this distribution also closely parallels the cargo status distribution for polluting tanker fire/explosion casualties. (refer to Figure 3-10.) For example, of the 409 incidents where the cargo status was known, 36% occurred with a cargo status of "loaded" compared to 41% for the polluting incidents.

Figure 3-15 presents the age of the tankers at the time of the reported fire/explosion incidents. Again, this assessment was conducted to determine if there was any obvious concentration of incidents with respect to the age of the vessels.

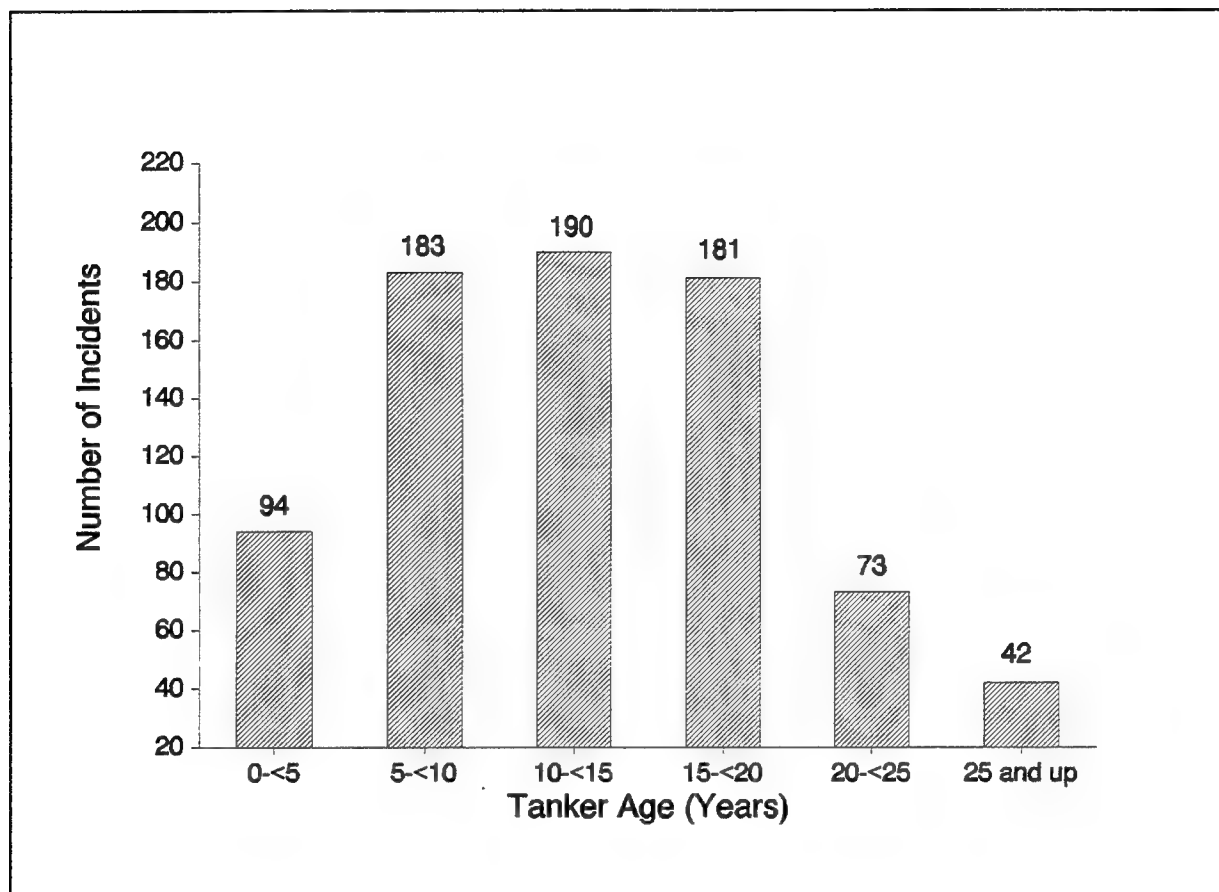


Figure 3-15

Age of Tanker at Time of Fire/Explosion Incidents,  
1978-1992 (ships of 1,000 GT and over)

Summary:

The age distribution for tankers experiencing fire/explosion casualties shows that for 85% of the casualties, the tanker was less than 20 years old.

[Note - This data is not normalized with respect to the age groupings of the tanker fleet. In follow-up conversation with MARAD, this tanker age grouping data was not available.]

Table 3-6 summarizes the number of reported tanker fire/explosion incidents by Flags of Registry for the five flags with the highest numbers of casualties over the 1978 through 1992 reporting period.

Table 3-6

Flags of Registry for Tankers Experiencing  
Fire/Explosion Casualties

Flag State	Tanker F/X Casualties (1978-1992)
Liberia	143
Greece	83
Panama	63
United States of America	55
United Kingdom	41
All Others	378

The tanker fire/explosion casualty experience for these five flag states were compared to the registry population data of the MARAD "Merchant Fleets of the World" report. Note that the casualty comparison was compared to the mean population for the years 1982 to 1992 for each flag state. This calculation is shown in Table 3-7.

Table 3-7

Tanker Fire/Explosion Casualty Rate by Flag State

Flag State	Tanker F/X Casualties (1978- 1992)	Tanker Population (1/1/92)	Tanker Population (1/1/82)	Mean Tanker Popula- tion	Tanker F/X Casualties/ Mean Tanker Population
Liberia	143	597	845	721	0.20
Greece	83	223	444	334	0.25
Panama	63	637	341	489	0.13
U.S.A.	55	201	296	249	0.22
U.K.	41	63	344	204	0.20
All Others	378	3,821	3,247	3,534	0.11

The results of this calculation are shown graphically in Figure 3-16.



Figure 3-16 summarizes the tanker fire/explosion experience for the years 1978 through 1992 by flag of registry.

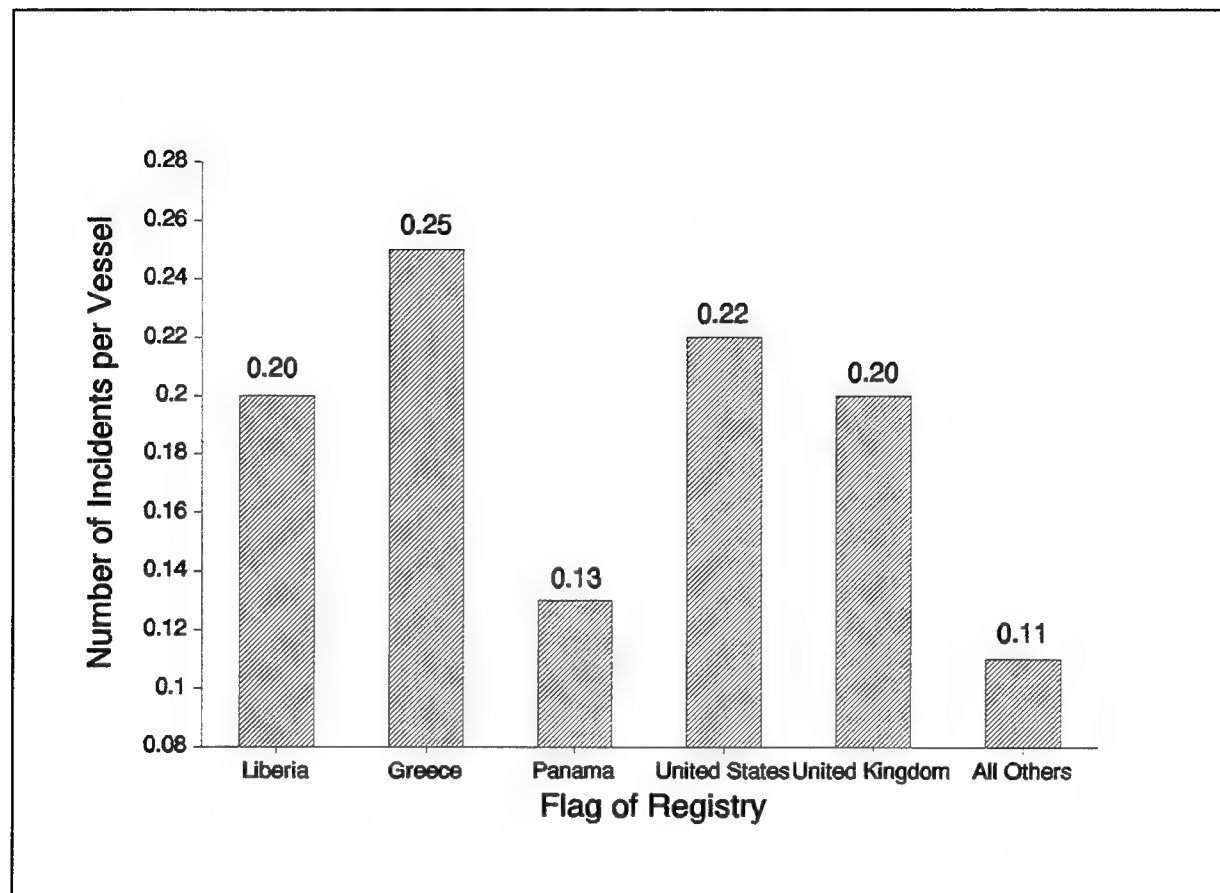


Figure 3-16

Number of Fire/Explosion Incidents per Tanker,  
1978-1992 (ships of 1,000 GT and over)

Summary:

Of the five flags of registry with the greatest number of tanker fire/explosion casualties reported, Greece, followed by the United States, Liberia and the United Kingdom had the highest number of casualties per registered vessel. These rates are significantly higher than those of the remainder of the flags of registry combined. Because of the dynamics of registry populations, these results may warrant a more detailed analysis using year-by-year population data. For example, note that the United Kingdom registered 344 tankers (over 1,000 GT) in 1982 and only 63 in 1992. It is believed that during this period owners were shifting their registry to the Isle of Man. Similar, but less pronounced dynamics are seen in the population data for the other four flag states as well.

Table 3-8 summarizes the numbers of reported fires/explosions by Classification Societies. For the purpose of this study this data was not normalized with respect to the Classification Society assignments to the tanker fleet population. As a point of interest, this data sort was conducted to determine the quantities of tankers involved in fire/explosion incidents which were certified by the Classification Societies.

Table 3-8

Classification Societies for Tankers Experiencing Reported  
Fire/Explosion Casualties

Classification Society (Listed Alphabetically)	"Serious" Fire/ Explosion Casualties	"Non- Serious" Fire/ Explosion Casualties	Total Fire/ Explosion Casualties
American Bureau of Shipping	66	97	163
Bureau Veritas	41	31	72
Germanischer Lloyd	10	12	22
Hellenic Register of Shipping	5	1	6
Indian Register of Shipping	2	2	4
Korean Register	3	4	7
Lloyd's Register of Shipping	94	125	219
Nippon Kaiji Kyokai	34	26	60
Norske Veritas	80	70	150
Polski Rejestr	1	1	2
Registro Italiano Navale	16	3	19
Registru Naval Roman	1		1
Register of Shipping USSR	4	1	5
Unknown Code or Null Entry	16	17	33

Summary:

The Classification Society comparison cannot be presented in the context of the total numbers of vessel types classed by each respective Society because this data was not available within the time constraints of this analysis. Additional information research would need to be conducted in order to reach any valid conclusions regarding casualty rates related to the Classification Societies.

### 3.5 FIRE/EXPLOSION EVENTS FOR ALL CASUALTIES

The vessel casualty reports maintained in the Lloyd's data base contain coded descriptions of up to five (5) events which sequentially describe the casualty. Casualties are categorized by their principal cause called the Basic Retrieval Group (BRG). Generally, this will be one of the first in a series of events which together describe the casualty. Considering the possibility that there could be significant fire or explosion events as part of casualties that were classified as other than fires/explosions, a survey of all casualty sequential events was performed to compare the individual events to their Basic Retrieval Group. The following Table 3-9 shows the results.

Table 3-9

#### Fire/Explosion Events Reported for All Casualties (Basic Retrieval Groups)

Basic Retrieval	Total Incidents	Fire/Explosion Events					Total F/X
		Event #1	Event #2	Event #3	Event #4	Event #5	
Collision	5,485	1	54	11	5	1	72
Contact	2,014	0	2	1	1	1	5
Foundered	766	1	3	3	0	0	7
Fire/Expl.	2,384	2,238	455	62	14	4	2,773
Hull/Mach.	8,755	27	11	4	0	0	42
War Loss	640	2	217	36	10	3	268
Missing	44	0	0	0	0	0	0
Wreck/Str.	4,052	2	17	9	2	0	30
Misc.	269	2	1	0	0	0	3

#### Summary:

Most casualties which included fire or explosion events were reported as fire/explosion casualties by their Basic Retrieval Grouping. The significant deviation from this finding is in the case of war losses. For this retrieval grouping, at least 1/3rd of the casualties included fire/explosion events. The number of fire/explosion events reported for the other retrieval groupings appears to be relatively insignificant in number, being on the order of 0.01% of the number of casualties.

### 3.6 SUMMARY OF SECTION 3.0 FINDINGS

#### Marine Pollution Problem

- There were 947 vessel casualties reported as resulting in pollution. Of these, fires and explosions totalled 56 incidents, ranking 7th out of the 9 casualty categories. Fires and explosions contributed to 6% of the reported causes, below wrecked, collisions, hull/machinery, contact, foundered, and miscellaneous, respectively.
- The tanker fleet is the largest contributor to the reported marine pollution problem, the freighter fleet is the second largest contributor in terms of numbers of incidents. In comparison to the freighter fleet, the tanker fleet experiences roughly four times the number of pollution incidents per vessel. The 528 reported tanker polluting casualties represent an average of 35 incidents per year.

#### Fires/Explosions/Pollution

- There were a total of 56 marine pollution incidents as a result of fires and explosions. The majority of these pollution incidents were reported on tankers (41 incidents). For tankers, this is an average of 2.7 pollution incidents per year (15-year reporting period) and represents a fire/explosion/pollution incident rate of approximately 0.05% of the tanker fleet per year.
- Of the 41 tanker fire/explosion/pollution incidents, 39 casualties were reported to be in the "serious" category. Fire/explosion casualties contributed to 8% of all tanker pollution incidents and rank 6th in frequency behind hull/machinery, wrecked, collisions, contact, and miscellaneous, respectively.
- Most of the casualty incidents are reported as "no" or "unknown" with respect to pollution.

#### Tanker Fires/Explosions/Pollution

- The most frequent site of fire/explosion casualties with reported pollution on tankers was in the area of the cargo tanks, for a total of 17 incidents (or 41%). Seven (7) incidents were reported to occur in the engine rooms (or 17%), and fourteen (14) of the incidents locations were reported as hull/unknown (or 34%).

- Approximately half of the incidents occurred while the vessel was at sea and the other half while the vessel was either at anchor or in port. This suggests that there is more of a problem with these incidents occurring while the vessel is in port or relatively close to shore since tankers minimize their in-port/at-anchor time to spend the majority of their operational time in the business of transporting cargo at sea.
- Forty-six percent of the incidents or (19) occurred to tankers that were in a loaded or partly-loaded condition. Thirty-two percent or (13) incidents occurred while the tankers were loading or unloading cargo. Twenty-two percent or (9) of the vessels were either reported as empty, in-ballast, or ballasting status.

### Tanker Fires/Explosions

- The most frequent site of the fires/explosions were reported to occur in the engine rooms (371 incidents) or 49%. 157 fire/explosion casualties occurred in the cargo tank areas or 20%. The remainder of the incidents were spread among hull/unknown/other, pump rooms and accommodation space. In contrast, for the 41 fire/explosion/pollution incidents reported in Section 3.3, the majority of these were found to occur in the area of the cargo tanks (41%), and (20%) were reported to occur in the engine rooms.
- Of the 371 engine room fires/explosions reported, (51%) of them were categorized as "serious" in nature. Very few of the engine room incidents were reported to cause pollution. The majority of "serious" incidents were associated with the boilers and main engines. The majority of people killed were associated with hot work/under repair. 36 of the 371 engine room fire/explosion casualties (or 10%) involved fatalities. In 87% of the 371 incidents the vessel was repaired and returned to service.
- There were 157 fires/explosions reported to occur in the cargo space areas, representing approximately 20% of the 763 total reported fires/explosions on tankers. Ignoring the incidents which occurred in the "unknown/other" circumstances, repair or hot work activities were taking place at the time of 68 out of the remaining 88 incidents. Seventy-nine of the 157 incidents (or 50%) involved fatalities.
- The age distribution for tankers experiencing fire/explosion casualties shows that for 85% of the casualties, the tanker was less than 20 years old.

- Of the five flags of registry with the greatest number of tanker fire/explosion casualties reported, Greece, followed by the United States, Liberia and the United Kingdom had the highest number of casualties per registered vessel. These rates are significantly higher than those of the remainder of the flags of registry combined. Because of the dynamics of registry populations, these results may warrant a more detailed analysis using year-by-year Flag State population data.

## 4.0 CONCLUSIONS AND RECOMMENDATIONS

### 4.1 CONCLUSIONS

Conclusions and recommendations are based on the three levels of analyses as follows:

- 1) The world wide fire/explosion casualty problem:
- 2) The marine pollution problem:
- 3) The tanker fire/explosion problem.

For the purpose of this study the Lloyd's data base provided comprehensive statistics on casualties experienced in the world fleet. This data base is most descriptive in the areas of damage to and disposition of the vessels, location of the incidents, and lives lost.

#### Fire/Explosion Problem

- Based on the Lloyd's reported data, fires/explosions account for 10% of all casualties for vessels  $\geq 1,000$  GT. On a fleet population basis:
  - Passenger vessels were reported to have the highest fire/explosion casualty rate with an average of 2.7% of the fleet experiencing a fire/explosion in a given year.
  - Tankers followed with an average rate of 0.9% of the fleet experiencing a fire/explosion in a given year.
  - Freighters and bulk carriers experience average rates of 0.5% and 0.4%, respectively.
- Fire/explosion casualties resulted in the 3rd highest number of vessels lost (600 vessels). Foundered (660 vessels) and wrecked (658 vessels) categories resulted in the highest numbers of vessels lost.
- The freighter fleet has shown a significant decrease in the number of fire/explosion incidents experienced (from an average of 100 decreasing to an average of 35 incidents per year).
- Fire/explosion casualties are the 2nd highest cause of fatalities (2,177 lives), following the foundered category (2,805 lives). The majority of these fatalities occurred on tankers and passenger vessels.
- In order for the Flag State data to be entirely reliable, the year by year Flag State population data would need to be analyzed.

### Marine Pollution Problem

- The wrecked category was reported as the most frequent cause of pollution incidents.
- Based on the number of casualty records with reported pollution, the fire/explosion category is not one of the leading causes of pollution incidents, ranking 7th out of the nine (9) categories.
- Tankers experienced the most casualties which resulted in reported marine pollution of all vessel types. The tanker polluting casualties represent an average of 35 incidents per year. Of these, fire/explosion casualties are a minor contributor (8%) or an average of 2.7 incidents per year (for an operating fleet of approximately 5,500 tankers).
- The leading categories of reported polluting incidents for tankers are hull/machinery, wrecked and collision.
- Most of the tanker fire/explosion/polluting incidents were located in the cargo area.

### Tanker Fires/Explosions

- The most frequent site of the tanker fires/explosions was in the engine room. Boilers/main engines appear to be the most frequent site of "serious" fires/explosions. Repairs or hot work were taking place at the time of the majority of the reported engine room fatalities. Overall, there is insufficient information about the factors contributing to the engine room fire/explosion incidents to develop any further conclusions.
- Most of the tanker cargo area fire/explosion incidents, where the circumstances were reported, occurred while hot work or other repairs were taking place.
- Approximately 50% of the cargo fire/explosion incidents involved fatalities.



## 4.2 RECOMMENDATIONS

The recommendations are general in nature reflecting the problem overview level of this analysis. A recommendation is made to improve the content of the world wide vessel casualty data to quantify regulatory effectiveness and support the development of new countermeasure initiatives. Several areas which require more detailed investigations or regulatory assessments are identified for the United States Coast Guard.

- Based on our detailed review of information provided by Lloyd's and cursory reviews of the USCG CASMAIN and NTSB data bases, there appears to be insufficient world wide detailed causal data available. In order to derive sound statistically based remedial actions and assess the effects of current regulated remedial actions for the world merchant fleet this data needs to be accessible. Therefore, we recommend the USCG support and promote the development of a comprehensive IMO casualty data base with the focus on collecting detailed causal data, including system and crew responses to the casualty (or alternately, that the Lloyd's data base be enhanced). All IMO member countries should be strongly encouraged to consistently participate in the submission of casualty data (anonymously, if need be).
- Based on the relatively high frequency of passenger vessel fire/explosion incidents and deaths with respect to the passenger fleet population, continue to promote fire safety design enhancements (i.e., automatic sprinkler initiative, smoke control, etc.), and fire safety training and awareness on passenger vessels. Develop an understanding of the factors effecting the significantly higher rate of fire/explosion incidents in the passenger fleet in comparison to the other fleet types.
- A significant common factor in tanker fire/explosion casualties and related deaths was hot work/under repair going on at the time of the incidents. Evaluate the effectiveness of safety procedures and safety awareness related to performing hot work and repairs on tankers.
- Develop an understanding of the factors effecting the significant reduction of fire/explosion casualties to the freighter fleet.
- The wrecked casualty category resulted in the most frequent number of pollution incidents. Investigate circumstances surrounding these type of casualties to learn about causes and common factors.

- Perform a follow-on analysis of the National Transportation Safety Board casualty investigative reports that provide much greater detail surrounding the circumstances of the casualty events. This analysis should focus on the more frequent polluting type casualties identified within this study, (i.e., wrecked for all vessels, and hull/machinery and collision categories for tankers). In addition, develop an understanding of the circumstances surrounding the fires/explosions occurring in tanker engine rooms (location of 49% of reported tanker fires/explosions). The analysis should also include identifying the common elements of NTSB recommendations within their reports.